SOIL CONSERVATION

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AGRICULTURAL ENGINEERING AND FARM PLANNING

By HOWARD MATSON [1]

IN planning farms for soil and water conservation the final plan represents a combination of recommendations involving the application of practices based on the sciences of soils, engineering, agronomy, and, in many instances, forestry and biology.

Since the knowledge and experience of each individual technician in the planning group constitutes an important contribution to the final plan dealing with each separate farm problem in relation to every other problem, it naturally follows that the engineer, as well as other technicians, must integrate his planning activities with those of other members of the group. The development of a practical farm plan for soil and water conservation that will treat each acre in accordance with its needs and adaptabilities, can be realized only when the various separate technical aspects dovetail or fit into the over-all plan.

In Region 4 experience has indicated that this can best be accomplished by "group" planning as distinguished from "one-man" planning. In soil conservation districts, the planning group usually consists of a farm planner and an agricultural enginner. Another technician may be added to the group where a major forestry, wildlife, or agronomic problem is involved. By training and experience, the farm planner ordinarily is able to give due consideration to the economic, agronomic, farm-management, forestry, and wildlife factors in developing an adequate land-use plan. It is the responsibility of the agricultural engineer to assist in coordinating needed engineering treatments and developments with other phases of the program and to make such surveys as may be necessary to ensure the adequacy of the engineering measures proposed.

Before the planning group goes to a farm to develop a plan, the engineer should make a careful study of the aerial photographs and physical land surveys covering the farm in question and all farms surrounding it. By this study he can determine the drainage pattern of the area, and in most instances he will be able to decide whether the farm may be considered alone or should be planned in conjunction with one or more of the surrounding farms. When farms are interrelated by drainage problems, the engineering measures and developments may be most effectively and economically applied if planned on a watershed- or drainage-pattern basis rather than by individual farm units. The engineer will find it helpful to prepare a drainage-pattern sketch for use in the field.

A thorough understanding of the agricultural engineering considerations involved, and their coordination with other phases of the program in the development of a farm plan, may be obtained through a study of the representative plan shown with this article. George Stewart lives in a recently organized soil-conservation district and, when he applied to the district supervisors for assistance, his farm was recommended to the district conservationist for planning. When the engineer examined the aerial photographs and physical land surveys covering the George Stewart farm to determine the drainage pattern, he found that Field 1 on the Stewart farm was affected by drainage from cultivated fields on the Ralph Blake and Fred Morris farms above, and that some of the terraces on Field 1 were emptying into a gully on the Blake farm along the property line. He discussed

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this problem with the district conservationist, who then asked the district supervisors to explain the situation to Ralph Blake and Fred Morris and to ask them if they would not like to have their farms planned in conjunction with George Stewart's. Since both men had been attempting to control erosion on their cultivated fields, they readily agreed.

The farm planner and engineer then visited this group of farms, taking careful notice of existing conditions and problems in each field, and discussing changes which should be made. Level readings were taken to determine the grade of existing terraces. They made frequent reference to the physical land-survey and land-use capability tables as a basis for decisions. The map at the left shows these three farms as they appeared to the planning group.

On the Blake farm the woods, Field 1, was not fenced and grazing and trampling had left the ground hard and almost bare. No selective cutting or stand-improvement practices had been followed. The run-off from a group of small springs in the woods was flowing into the pasture, Field 2, but there was no good watering place for stock.

The terraces in the north part of cultivated Field 4 had satisfactory grades but were somewhat lacking in channel capacity. They emptied on to well-established sod, and no erosion was occurring at the outlets. The land along the drainageway was being cultivated, however, and erosion was evident as a result of overflows. The terraces in the south part of this field had satisfactory grades, but they were emptying into a gully along the property line and the terrace channels were beginning to gully at the outlet ends.

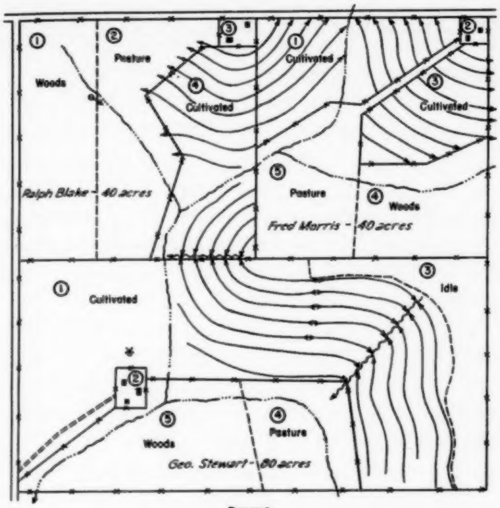
The terraces in the west part of Field 1 of the Fred Morris farm were small, had an average grade of 8 to 9 inches per 100 feet, and the four top terraces were emptying into a badly gullied roadside ditch. The same was true of the terraces in the east part of the field, and part of this slope was too steep and badly eroded to remain safely in cultivation. The fence along the roadside ditch was undermined by gullying. The terraces in Field 3 were in the same condition and were emptying across the property line on to an adjoining farm and causing gullying. The woods in Field 4 were not fenced and were in about the same condition as Field 1 of the Blake farm. The pasture, Field 5, was well sodded but was small, and no water was available except at the farmstead.

The west part of Field 1 of the George Stewart farm was in cultivation but not terraced, and was too badly eroded to remain safely or profitably in cultivation. The terraces in the east part of Field 1 had excessive grades and were inadequate in size. Most of them were emptying into a gully in the center of the field, but five were emptying across the property line into a gully on the Blake farm. Field 3 was a steep, rocky patch of idle land covered with weeds, scattered brush, and trees. The pasture in Field 4 was fairly well sodded but was too small for the needs of the farm and no water was available except from a tank at the farmstead. The woods in Field 5 were unfenced, grazed, and in poor condition.

The map at the right illustrates the plan for these three farms as developed by the planning group. The woods in Field 1 of the Blake farm are to be fenced and good management practices will be followed. A covered collecting basin will be built for the springs, and the water will be piped to a stock-watering tank to be built at the west side of the pasture, Field 2. The pasture will be mowed to control weeds, and no other treatment will be necessary. The terraces in Field 4 will be built up to adequate size as soon as the present cotton crop has been picked, and a recommended method of strip cropping will be used. The field road will be along the east property line.

The land adjoining the drainageway will be retired from cultivation and developed into meadow, to prevent further erosion damage and to provide a source of hay, and will become new Field 5. In new Field 6, the old terraces will be leveled, and new terraces will be built as an extension of the terraces in Field 4 of the Stewart farm, emptying upon the established pasture, Field 2, of the Morris farm. A recommended method of strip cropping will be used. A drainage agreement among the three land owners will be put into execution, and this will include responsibility for construction and maintenance. Access to this field is available only over the terraces, but this will not be necessary more than once or twice a year when crops are harvested.

The terraces in Field 1 on the Morris farm will be leveled, and new terraces of adequate size and proper grade will be constructed to empty into the road ditch. The county has agreed to cooperate with the soil conservation district and the landowners in executing a protective highway agreement as indicated along the north side of the Blake and Morris farms. In the section west of the culvert, the water-carrying channel which will receive run-off from the four terraces in Field 1 will be solid-sodded as soon as resectioning has been completed by the county, and the flumes on each side of the culvert will be solid-sodded. The side slopes of the west section and all of the east section will be broadcast-sodded.



Present

In the pasture, Field 2, a stock pond will be built to provide water for livestock. Core tests were made, and subsoil conditions were found to be favorable for the construction of a pond. The sodded spillway will be on the north side of the pond, to divert the run-off from the pond to the adjoining stable drainageway. The pond will be fenced, and water will be piped through the fill to a stock tank below. The upper part of Field 2, which is to be retired from cultivation to pasture, will be manured, sodded, and cultivated at least twice during the first growing season to establish a good cover as soon as possible.

The terraces in new Field 4 will be left as they are for the present. As soon as a cover is well established in the pasture, Field 2, the terraces will be leveled, and new terraces of adequate size and proper grade will be constructed to empty into Field 2. A recommended method of strip cropping will be used. The field road will be located next to the east property line. The woods in Field 5 will be fenced off from the pasture and proper management practices will be followed.

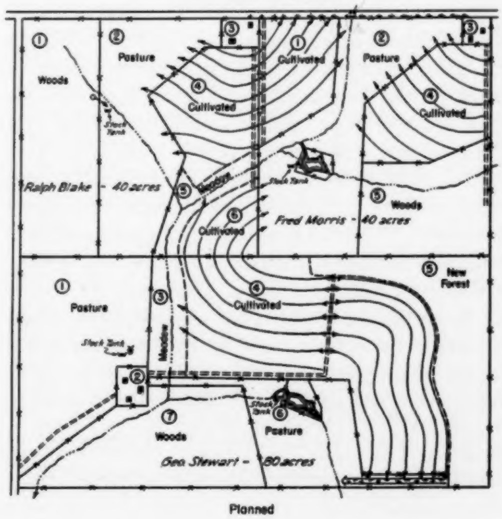
Field 1 of the George Stewart farm will be retired from cultivation, fenced, and sodded to pasture. Numerous small gullies will be plowed in, manured, and sodded. The field will be contour furrowed to keep as much water as possible out of the gullies. Water will be provided by a stock-watering trough to be built near the windmill on the farmstead.

The land adjoining the drainageway on the Stewart farm will be retired from cultivation and developed into a meadow as indicated, becoming new Field 3. In Field 4, the old terraces west of the field road shown will be leveled, and new terraces of adequate size and proper grade will be constructed to extend through Field 6 of the Blake farm and empty into the pasture, Field 2 of the Morris farm as described above. The old terraces on the other side of the roadway will be left to empty into the gully for the present until the short sodded channel at the south side of the field can be excavated and time allowed for the broadcast-sod to become established. This should be within a year, after which the old terraces will be leveled and new terraces of adequate size and proper grade will be built to cross the gully which was formerly used as an outlet and to empty into the short sodded channel. This channel will empty into the drainageway over a sodded flume. The upper terrace will be built with sufficient capacity to divert the run-off from the new forest, Field 5. A recommended method of strip cropping in connection with terraces will be used in Field 4. It should be noticed that the terraces were divided and run in opposite directions because of their length, and that this division point is the logical location for a field road.

Pine trees will be planted in Field 5, which was formerly idle land. A border strip of three to five rows of adapted shrubs will be planted between the pine trees and cultivated field. This border strip is for the purpose of improving conditions for wildlife and will prevent the eventual shading effect that the trees would have on the field crops.

In the pasture, Field 6, a pond will be built to provide a water supply for livestock. Core tests were drilled,

(Continued on p. 195)



Planned

LAND UTILIZATION DEVELOPMENT

By HUGH R. McCALL [1] AND ASSOCIATES [2]

THE development of nearly 7 million acres of purchased land—submarginal, cut-over, overgrazed, and otherwise misused—as initiated under the Resettlement Administration in December 1935, involved 94 land-use demonstration projects located in 41 States. The principal objective of the program was to achieve the best multiple use of this land through public ownership and management. Besides beneficial land-use adjustments the program provided employment in areas where the unabsorbed relief load was high and where the opportunity for other work projects was limited.

In the eastern half of the United States the utilization of the areas was directed toward nonagricultural uses such as forestry, recreation, and wildlife conservation. This required extensive timber-stand improvement and tree planting, construction of many impounding dams, and recreation facilities of all kinds. Hundreds of miles of roads and telephone lines as well as numerous administration and service buildings were provided. In the Great Plains and intermountain areas this adjustment has involved the development of range-improvement measures to facilitate constructive range management. On these projects hundreds of stock-watering places, miles of fencing, and extensive reseeding were needed. Grazing control and other water- and soil-conservation measures also were necessary.

Since 1937 the submarginal-land program has been conducted under authority of title III of the Bankhead-Jones Act, and development work was initiated on 22 additional projects after the entire program was transferred to the Bureau of Agricultural Economics by administrative order. More specific instructions by Congress concerning the types of land to be purchased under this act resulted in the formation of a program more strictly concerned with agricultural problems. The development work has consisted principally of improving the purchased lands for grazing and forestry purposes. Most of these later projects are located in the northern and southern Great Plains because of the pressing need for rehabilitation in this region. The greater amount of the work has been conducted in cooperation with State and local agencies.

The funds and labor, certified from local relief rolls, have been made available through the cooperation of the Works Projects Administration. At one time a maximum of 43,000 men were actively engaged in this development work and this number included many of the clients whose land had been purchased by the Government.

Following the reorganization of the Department of Agriculture in 1938, the administration of this program was transferred from the Bureau of Agricultural Economics to the Soil Conservation Service, where it has been integrated with other departmental programs for the conservation and proper use of lands.

The following summary of the major jobs completed during the period beginning in December 1935 and extending through the fiscal year 1938–39 will furnish some indication of the detailed nature, extent, and diversity of the work undertaken on these project areas.

Job classification		*Units completed*
Obliteration of fences	miles	7,333
Obliteration of farmsteads		5,320
Seeding	acres	185,380
Roads	miles	1,121
Truck trails	do	4,191
Bridges		1,482
Telephone lines	miles	2,287
Power lines	do	108
Lookout towers		162
Impounding dams		1,635
Earth dikes	miles	30
Administration buildings		144
Cabins		327
Work camps (146 total units)		28
Bathhouses and shelters		191
Other building structures (service buildings, equipment sheds, garages, barns, latrine buildings, etc.)		828
Camp fixtures		5,413
Public camp and picnic grounds	acres	11,996
Water-supply systems		345
Wells, pumps, and windmills (stock water)		505
Sewage-disposal systems		192
Fences	miles	6,045
Cattle guards		813
Corrals		55
Terracing	rods	210,285
Contour furrowing	acres	25,158
Check dams		389,058
Stand improvement	acres	452,402
Fire-hazard reduction	do	252,380
Trees planted and seeded		67,950,000
Stream improvement	miles	936

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[2] Other members of the engineering division, particularly Messrs. E. J. Thomas, John B. Thomas, Louis Brandt, and William A. Holweg contributed material and data incorporated in this article.

Additional activities not included in this tabulation involve land clearing, quarrying and crushing rock for liming the land and for construction use, timber harvest, firebreaks, boundary markings, cover mapping, acquisition, topographic and drainage surveys, fish-rearing ponds and hatcheries, food and cover planting, and biological conditioning work.

Because of the extensive structural work involved, engineering has been a predominant feature in planning and supervising the development of these projects. The building of structures necessitated making surveys, plans, detailed designs, specifications, cost estimates, and work schedules to ensure efficient execution of the work. The important details of certain representative structural facilities are described in the following to show the great amount of engineering work involved.

Impounding Dams

A total of 1,635 impounding dams have been built to date. While all can be considered in the general category of small dams, a limited number are structures of considerable size. They range in type, size, and utility from the great number of small stock-water reservoirs serving the livestock grazing areas of the semiarid regions of the West to the larger rolled earth-fill and masonry gravity types constructed for water-conservation, wildlife, and recreational purposes.

In planning a network of stock-water reservoirs in a given area, the selection of individual sites was important from a range-management as well as a construction point of view. Factors requiring careful evaluation were the location of sites with respect to the distribution of grazing and accessibility for cattle, the impounding of the maximum volume of water with ample depth and minimum amount of earth embankment, the status of land ownership, the ratio of storage capacity to the estimated annual yield of the drainage area, and the adequacy and type of spillway best adapted to discharge economically the maximum expected flood flow. The physical dimensions of these reservoirs vary widely with local topography. In general, they range from 1 to 5 acres in area, with a maximum water depth of from 8 to 15 feet. The dam structure is usually from 150 to 400 feet in length, with an embankment volume up to 5,000 cubic yards. To date, over 700 of these structures have been built on the three Montana projects.

Other examples of small dams required under the program are the concrete and timber spillway types constructed across drainage ditches in the central Wisconsin and northern Minnesota areas.

The 1,500-acre Rynearson flowage at the Central Wisconsin Game project near Necedah, Wis., is controlled by two of these concrete structures capable of holding a 15-foot head of water and discharging the overflow through multiple 8-foot span openings. They are equipped with removable timber stop logs and, in addition, one structure has a 16- by 8-foot steel taintor gate, thus giving flexible control of water levels during periods of flood flow. The remaining integral part of this flowage is formed by 2.2 miles of shallow earth dike constructed across the flat sand and peat land depressions between protruding small islands in this glacial marsh area. On the 152,000-acre purchase area of both central Wisconsin projects, 30 miles of earth dike (350,000 cubic yards of embankment), 24 timber and 3 concrete spillway control dams have created an open water area over 8,000 acres suitable for the propagation of migratory waterfowl and fur-bearing animals.

On the Beltrami and Pine Island projects in northern Minnesota, 210 small timber ditch dams have been built to raise the water table previously lowered by the extensive drainage program carried out in this peat-bog area during the period 1912–17. Several hundred miles of ditch profiles have been run as a basis in selecting sites for optimum flowage. These ditch flowages have saturated the surrounding peat marshland, and thus they serve as an effective firebreak in this territory. These dams are also of inestimable value in providing conditions suitable for the propagation of waterfowl, small fur-bearing animals, and such big game species as moose, elk, deer, and caribou.

The larger rolled earth-fill types with reinforced concrete spillways and channels are represented by the Tierra Blanca Dam near Umbarger, Randall County, Tex., and the Greenwood Dam located on Furse Creek near Shoals, Martin County, Ind. These dams form a nucleus for an extensive recreational and wildlife development. The Tierra Blanca Dam is shown in the accompanying illustration.

The Greenwood Dam forms an 800-acre lake with 12,000 acre-feet of storage; it spans the flat valley of the Furse Creek with a drainage area of 13 square miles of rough, unglaciated terrain, typical of this section in southern Indiana. This valley, lying in a general east-and-west direction, has a large neck of high land projecting from the south valley wall to within 1,200 feet of the north wall, and thus it offers an excellent site for an earth-fill dam. A fill of 217,743 cubic yards that was 1,320 feet long and 16 feet across the top was used. Foundation explorations revealed

Tierra Blanca Dam, Randall County, Tex. Length of earth fill, 835 feet; top width, 16 feet; height, 53 feet; volume of fill, 135,379 cubic yards; volume of concrete, 2,960 cubic yards; length of spillway crest, 200 feet; length of spillway channel, 700 feet; width of spillway channel, 80 feet; reservoir area, 1,870 acres; storage capacity, 18,120 acre-feet; drainage area, 575 square miles; spillway capacity, 50,000 c. f. s. (200-year flood frequency); depth of water May 9, 1939, 19.3 feet; dewatering conduit, 4 by 5 by 200 feet (reinforced concrete).

that the site in years past had been the location of a natural lake with the high land reaching out as part of the old natural dam embankment. The original lake bed, now under 10 to 12 feet of topsoil, consists of a dense blue lake silt to a depth of approximately 50 feet. From a geological point of view, this depth of silt would indicate that the natural lake had occupied this bed for hundreds of years.

Because of the investment involved and the importance of protecting life and property, these and other large dam structures required a high standard of engineering design and construction. For earth-fill dams the material was placed in 6-inch layers and thoroughly compacted by the use of sheep's-foot roller equipment. The moisture content of the fill was also carefully controlled by sprinkling, and the latest principles and methods of soil mechanics were employed.

The spillways on the larger dam structures are either ogee, channel chute, or side channel, as best suits the site, and are constructed of either concrete or native rock masonry. In the designs, architectural and aesthetic effects have been combined to produce a pleasing appearance in harmony with the local surroundings.

As might be expected, a program of such a large number of dams gave rise to many engineering problems. One of the most difficult has been estimating flood flow that must be provided for. Not only factors of topography, geology, meteorology, climate, and vegetal cover are involved, but also the intangible matters of probability, economics, and public policy. The disposal of flood waters after passing through the spillway has been another important design consideration. Due to kinetic energy and velocity accumulated in the rapid transposition in elevation, water can cause great damage to the spillway, dam structure, or the valley below if unleashed without control.

The geological structure of the foundation frequently has been a major problem of design. Foundations must be stable and capable of supporting the structure. Further, they must be either impervious, or, if pervious, capable of transmitting percolating water at a safe low velocity so as not to disturb the soil particles. The volume of seepage must be restricted so that it will not cause any serious loss of water from a reservoir. In rock foundations, the existence of possible seams, fissures, faults, and limestone caverns must be investigated. If there is danger of excessive seepage, a deep cut-off, sheet piling, or pressure grouting may be required. In some instances a broad, impervious upstream apron will prove effective.

At the Storm Creek Dam near Helena in eastern Arkansas, the problem encountered was unique, because of a very peculiar geological formation and an unusual soil type. This dam is located in Crowley Ridge, a prominent topographical feature of the region, elevated 150 feet above the surrounding flat bottomlands of the Mississippi Valley. The ridge extends 125 miles in length and approximately 3 miles in average width. Its eminence is due to the effects of differential erosion by the great drainage systems of the region; the Mississippi River and its tributaries in Quaternary times have worn away vast areas on either side of the ridge, but by curious chance the stream cutting missed this narrow area. Subsequently, the ridge was capped by a thick deposit of wind-blown loess, which is now the dominant soil type of the area. This loess is an extremely fine silt and contains a negligible amount of colloidal material. The soil particles are elongated in shape and uniformly small and ungraded. The soil has an unusually low density, high porosity, erodes readily, and is almost impervious to percolating water. It also has a very narrow range of critical moisture content. In many characteristics it behaves in a perverse and paradoxical manner.

This was the material available for the construction of this large dam. The fill was deposited and spread in 6-inch layers and compacted by a heavy sheep's-foot roller making approximately 20 trips for each layer placed. Even with the greatest care the density obtained was only a dry weight of 87 pounds per cubic foot, or an increase of 12 percent over the weight in situ at the borrow pit.

A scene in the Sand Hills project, Hoffman, N. C., where 12 miles of trails have been reconstructed to form a sand-clay surface park road leading from main highways through the Indian Camp Park recreational area. Work involved clearing of 15 acres, excavating and grading 12,000 cubic yards, placing of 450 feet of 18-inch and 24-inch concrete pipe culverts, and building of 4 small timber bridges.

For the protection of the upstream face, a blanket of pit run gravel was applied having a horizontal thickness of 3 feet at the top to 10 feet at the base. It was deposited in layers concurrently with and rolled integrally with the rest of the fill. The upstream face was further protected against continuous wave action to a vertical height of 7 feet by firmly keyed sacked concrete. This type of riprap was employed as there was no rock available in this region. The downstream slope was protected by solid sodding of Bermuda grass to resist erosion. Riprap was also placed on the lower 12 feet of the downstream slope which is subject to backwater action caused by floods of the Mississippi River. This dam spans a broad valley and has a tributary drainage area of 9 square miles. It is 1,100 feet in length and 45 feet in maximum depth. Slopes are three to one upstream and downstream with a 30-foot width at the top. Approximately 250,000 cubic yards of embankment have been placed for this structure.

Buildings

The future public use and management of these project areas by State or Federal agencies has made imperative the construction of a great number of permanent building structures serving many different purposes. At administrative centers individual or combination units are necessary for tool and equipment storage, garage facilities, warehouse supplies, office use, and superintendents' quarters. Also, many dwellings are required for forest rangers, game managers, maintenance workers, or others having responsibility for management and supervision who must reside on the project. Complete engineering surveys are required in locating and planning the general layout of groups of buildings serving the various headquarters areas.

Recreational developments call for a variety of buildings such as bathhouses, boathouses, cabins, lodges, recreational buildings, and picnic shelters, which generally vary in style and type of construction according to their local environment. The general approach in the design of these facilities has been the so-called rustic construction. This enabled the utilization of project labor to produce native materials needed for construction. This is particularly important in the present stage of development, because of the limitation of funds imposed for the purchase of materials and supplies. On many projects sawmill operations also are carried on for cutting, drying, and planing the lumber used in the building of frame structures. On the Sand Hills project in North Carolina all lumber required for the fish hatchery and game farm buildings, in addition to the Millstone Group Camp and Indian Park Recreational Area, was provided by this method.

Organized group camps or recreational centers for 4-H Clubs and Boy and Girl Scouts have proved exceptionally popular. The buildings for most group camps consist of staff quarters, infirmary, administration building, dining hall and kitchen, numerous bunk cabins, bathhouses, toilet buildings, and a club or assembly building. An unusual example of this type of facility serving a dual purpose is the Lakeview Camp on the Allegan, Mich., project. Here a camp was provided to house 150 workers during the intensive stage of development operations on the project and later to be used as a permanent recreational camp for various youth organizations. These buildings have recently been given a more permanent exterior finish of beveled bungalow siding and new roofing. The camp is well landscaped and is situated on a promontory overlooking Lake Allegan, formed by the new Allegan Municipal Power Dam across the Kalamazoo River.

Sanitary Installations

One of the problems most difficult of solution is that of securing an adequate, safe, and potable supply of drinking water. This should be the first requisite in planning an administrative headquarters, group camp, or recreational area. Its importance, together with that of providing a safe means of sewage disposal, cannot be overstressed, as the future effective administering of these centers may be impaired by the inadequacy of sanitary installations. In fact, the development of a water supply should be given priority in construction, for the additional purpose of facilitating the building of other structural units.

In the construction of individual dwellings, it has been kept in mind that the water supply and sewerage installations should be of the type most suited to the respective locality and requirement. Although modern bathroom fixtures were considered desirable in residences where water could be made available under pressure, the hand pump was resorted to at many forest wardens' dwellings and workers' cabins where funds were limited. When the type of dwelling and demand justified power pumping equipment, a pressure tank, concrete reservoir, or elevated tank for storage was installed. Drilled wells with a minimum diameter of 4 inches were recommended, but smaller sizes were used when the drilling could be performed by project labor and a sufficient water yield secured for the requirements of the site. Water-carriage sewage-disposal systems have been constructed at individual dwellings where feasible. However, approved standard fly-proof pit privies were the only alternative when only a hand-pump water supply was available. Septic tanks having a minimum liquid capacity of 500 gallons with subsurface tile fields were built when water could be secured under pressure. Springs have been developed only when a sanitary survey indicated that their safety could be assured, and cisterns with filters were used where a well supply would have been extremely expensive.

At the larger recreational centers water systems involving elevated tanks or storage reservoirs with capacities of from 5,000 to 12,000 gallons were necessary. With these installations sufficient head and pressure were available for a gravity distribution system to the various parts of the recreational area. Dual systems using lake water for the showers and toilets were necessary when an adequate safe supply of water for all requirements could not be secured. To eliminate the possibility of infection through the use of these showers, the installation of portable chlorinators for treatment of water was recommended. The principal of chlorination has also been employed at swimming pools to maintain a consistent chlorine residual for protection of the health of the individuals using the bathing facilities.

The problem of providing for the disposal of sewage from all buildings or group camps or recreational areas has required numerous field investigations. Large septic tanks with siphons and adequate disposal fields based on soil percolation tests were constructed to serve the lodge buildings and camp groups. Separate individual systems were designed when the general terrain did not permit the serving of the entire area by one central system. The bathhouses had separate

Watchman's cabin for lookout tower, Allegan project, near Allegan, Mich.

shower-water disposal systems and the domestic sewage effluent only was carried to the septic tanks, thus permitting better operation of the treatment system. Imhoff tanks with trickling filters were not desirable due to the regular supervision these systems entail, and the possibility of odor nuisances unless they were located a considerable distance from the general use area.

The sanitary care of buildings as well as proper garbage and refuse disposal has largely been a problem of educating the public using these areas. In this connection a sufficient number of garbage containers and incinerators were placed at convenient locations for disposal of all refuse.

Other Structural Facilities

Other major structural facilities constructed under this program include 4,191 miles of truck trails, 1,121 miles of park roads, 1,482 bridges, 2,287 miles of telephone line, 162 lookout towers, and 6,045 miles of fencing.

Several of the original projects already have completed development and are turned over to administrative agencies, and a great majority of those now continuing development operations will be liquidated during the current fiscal year. Although the Soil Conservation Service is continuing to administer the major portion of the demonstration projects set up under this program, wherever it has been more appropriate the lands have been transferred to a State or Federal agency for permanent management. A considerable acreage already has been transferred to the Forest Service and the Biological Survey for incorporation into national forests and game refuge areas.

A forthcoming issue of SOIL CONSERVATION will feature other phases of the land utilization program.

THE WATER-FACILITIES PROGRAM

By KARL O. KOHLER, JR.,[1] AND JAMES A. MUNCEY [2]

THE water-facilities program is so designed that facilities are not to be developed "hit-or-miss" or for a great variety of purposes. Carefully planned water facilities are intended to achieve wiser use of land over a period of years and, through wiser land use, to promote the welfare of the people who live on the land.

According to the Water Facilities Act, facilities cannot be located where they will encourage cultivation of lands that are submarginal for agriculture. The benefits of the program are extended to bona fide farm or ranch operators—those whose lands are in actual use for agricultural or grazing purposes or may profitably be placed in such use as a result of water-facilities work. The intent of the act is to provide for a great number of small water facilities rather than a few large ones. It is expected that the majority of the individual facilities to be constructed under the program will cost less than $2,000 each; thus with the funds available a greater number of people will be benefited. In some instances larger, more costly facilities may be required, and to provide for these the Agricultural Appropriation Act of 1940 establishes $50,000 as the maximum amount of Federal funds to be expended for any one facility.

Only facilities that will benefit lands in private ownership will be built. Facilities are not installed on public lands except when it has been shown that they are necessary to provide needed water supplies for farm or ranch families on adjoining or interspersed non-Federal land.

Tenants as well as landowners may benefit from the program. Before a tenant can participate, however, he must provide security for the loan and the lease must be arranged to insure to him benefits that will offset his contributions to the cost of installation. A landowner must also provide security before a loan can be granted him. The security required will be based on a reasonable probability of repayment of the loan as reflected partly by the farm plan and partly by the present value of the security.

Under certain conditions it may be desirable to provide a facility that benefits a group rather than an individual. This can be done through the use of such an instrumentality as a cooperative association, a mutual water company, irrigation district, or a soil-conservation district.

To promote better land use for the maximum number of farm families in a drainage area where water supply is limited, careful planning for the watershed as a whole is required. In watersheds authorized for planning under the program, local farmers, acting through county agricultural land-use planning committees, take part in the development of the general plan for the area. These county committees function cooperatively with the State land-grant colleges and the United States Department of Agriculture. The Department's participation in this planning work is under the leadership of the Bureau of Agricultural Economics.

The Soil Conservation Service has been designated as the agency of the Government that will build or supervise the building of water facilities in areas which have been approved for operation. The Farm Security Administration will handle the credit aspects of the program.

Persons desiring to benefit from the program may consult the local representative of the Soil Conservation Service or the Farm Security Administration, the county supervisor, or the county agricultural extension agent. These men will know which areas are included in the program and whether or not help is available locally.

It is essential that a conservation plan and a farm and home management plan be worked out cooperatively with each individual farm or ranch served by a federally financed water facility. Therefore, every farmer benefiting must agree to carry out a farm plan as a consideration for receiving the financial and other assistance offered by the program. These farm plans will be drawn up by representatives of the Department and the cooperating farmer or rancher. They will provide for (1) the application of soil- and moisture-conservation practices, (2) improved land use, (3) a production plan that provides for repayment of loans and operating and living expenses, and (4) sufficient food and feed crops to meet the needs of the family and the livestock. The farmer must agree to maintain the facility during its useful life.

The amount of the loan that the farmer is expected to repay will depend upon his ability to repay. Ability to repay will be determined by the Department. The number of years the loan will run will depend on

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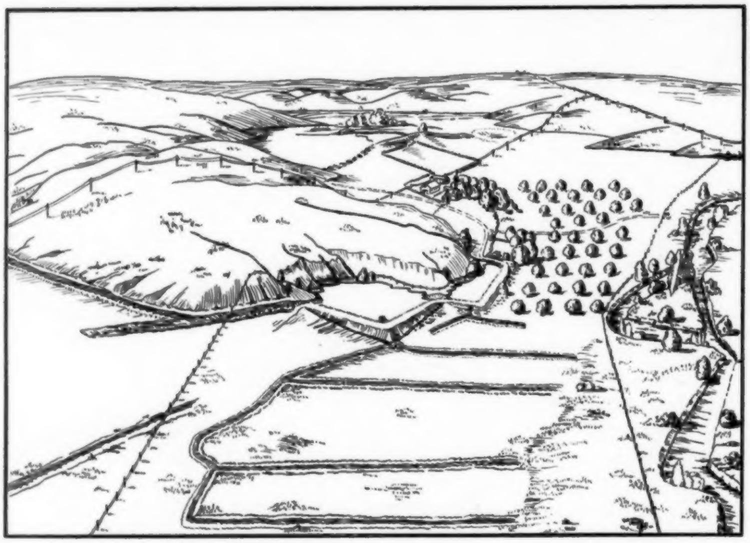


Figure 1.—A sketch of the ranch near Tascosa, Tex., showing the facilities developed under the water facilities program.

the expected life of the facility, but in no case will it exceed 20 years. Interest will be at the rate of 3 percent per annum. The Department will not ask reimbursement for its assistance in engineering, legal matters, and farm management; that is, it will not expect reimbursement of the costs of general administration of the program.

The program offers Federal assistance in constructing, installing, repairing, or rehabilitating the following specific kinds of facilities: Ponds; reservoirs; wells; detention, retention, and diversion dams; pump installations, including windmills; spring developments; water spreaders; stock-water tanks; facilities for flood irrigation and small irrigation facilities, either for individual families or small groups of families; facilities for recharging underground reservoirs.

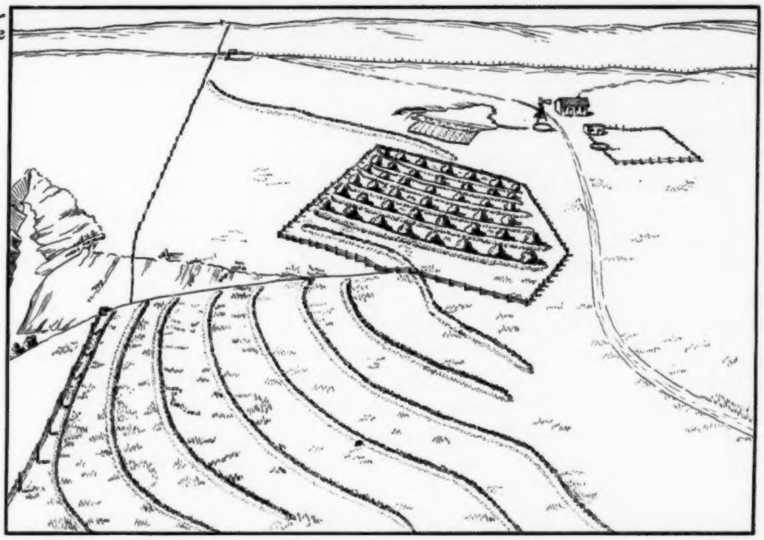
Only such facilities may be provided which in actual operation will effect the storage or utilization of water for stock or farmstead use or for its application to farm gardens, crop or hay lands, range or pasture lands, or other lands used for agricultural purposes.

Actual construction and installation of facilities can be handled either by (1) having the Department do the job, or (2) by making the necessary funds available to the benefiting farmer or rancher (or cooperative association) and having him assume responsibility for getting the job done.

A family living near Tascosa, in the Texas Panhandle, had long dreamed of a maximum development of water facilities on their ranch of some 3,700 acres. They knew that such development was possible; but it was not until technical services and reasonable cost of financing as provided by the water-facilities program were made available that their dream approached realization. An analysis of the situation as it existed on their ranch revealed that they had two major problems, the production of supplementary feed for their livestock, and serious annual floods. The sketch (fig. 1) shows a more complete picture of this problem.

Surveys revealed that the flood damage was being caused by flash run-off, from 337 acres of rough broken land, that was draining into a draw which overflowed on to fields and damaged orchard, roads, and farmyard. To prevent this damage, an earth-fill dam was constructed across the draw above the farmstead. A diversion was also constructed to intercept water flowing across the farmyard and divert the flow into the reservoir. This retention dam is approximately 800 feet long, 12 feet high at the maximum, has a crown width of 12 feet, and contains approximately 7,000 cubic yards of fill. Side slopes are 2 : 1 downstream and 3 : 1 upstream, with the upper face riprapped with rock. A storage capacity of 30 acre-feet is provided, and grain fields below can be irrigated by discharge of water through an 8-inch pipe through the dam. Because of the gradual percolation of water into the sandy soil, it is not anticipated that much water will be available for irrigation from this reservoir. This is considered an advantage, however, in that it provides a recharge for several springs which outcrop just below the farmstead. An adequate spillway is provided to take care of expected floods. Water discharged from the spillway is spread over pasture land to provide intermittent irrigation for the grass.

Figure 2.—A view of the water facilities installed on the Texas Panhandle farm.



Development of irrigation facilities for the production of a dependable source of supplemental feeds was of fundamental importance on the ranch. Prior to this development the discharge from the several springs below the homestead had been stored in two small ponds having a combined capacity of about 15 acre-feet. Water from these ponds was used to irrigate 10 acres of orchard and to provide water for livestock. Since the capacity of these small ponds was not adequate to impound all the discharge from the springs it was decided to provide additional storage. To do this a second earth-fill dam was constructed below the two small ponds, and thus an additional 30 acre-feet of storage was provided. This dam is approximately 800 feet in length, has a maximum height of 16 feet, a crown width of 12 feet, and contains approximately 15,000 cubic yards of fill. The design calls for slopes of 2 : 1 downstream and 3 : 1 upstream with the upstream slope also riprapped with rock. Water may be discharged for irrigation through a 15-inch corrugated-iron, paved-invert pipe controlled with a vertical 15-inch cast-iron gate operated from a substantial catwalk. To supplement the spring flow, a diversion channel was constructed to divert run-off water from 100 acres of pasture land into the reservoir. Directly below the reservoir lies a 45-acre field. This entire field can be irrigated from the reservoir and is to be planted to alfalfa. Leveling operations have been completed and ditches and laterals constructed. The production of alfalfa on this field, for feed to supplement the grain sorghums grown on nonirrigated lands. is a valuable contribution to the ranching program.

The dams were constructed with 60-hp. crawler-type tractors and 6-cy. (capacity) carry-alls. Earth was placed in layers of 6 to 8 inches and well compacted. The owners gave splendid cooperation during the entire construction; they contributed a large part of the labor, operated the equipment a part of the time, did all the rock riprap work, fence work, construction of the catwalk on the second dam, and were a constant inspiration to the construction crews. The total cost of this facility was approximately $3,500. Of this amount the owners contributed about 50 percent in labor and materials. The owners will repay the remaining 50 percent to the Government over a period of 20 years.

A farmer in Hartley County, in the Texas Panhandle, also is thankful for the service provided by the water-facilities program. Before the development of this facility he had no water either for livestock or domestic use. Domestic water was hauled from a well at an abandoned farmstead three-fourths of a mile distant. Since he had no stock water on his farm he could not utilize his own grazing land, but had to arrange to graze and water his livestock on a neighboring farm. His tenure was very insecure; it was necessary to renew the lease annually. Through reorganization of his plan of operations, which was a requirement in the development of plans for the facility, he secured a 12-year lease making it possible for him to construct improvements (fig. 2) with confidence.

Water was provided from a well 380 feet deep cased with 6-inch casing. A 12-foot windmill on a

32-foot wooden tower was installed. Water is pumped through 2-inch tubing and has proved ample for livestock and domestic purposes. The windmill was located on a high spot where the operator has since built a new house. Overflow from the windmill is carried into a storage tank which was constructed by damming up a small draw. Run-off from the draw, together with the overflow from the windmill, will be stored behind this small dam. Provision is made for irrigation of a 1-acre garden plot directly below the dam by discharge of water through a pipe. The installation of this facility has made it possible for the farmer to keep several head of dairy stock with which he will supplement his income by selling cream. The skimmed milk will be fed to his hogs. Below the stock pond is a wide, flat meadow in which abundant natural grasses have grown in the past. The surplus water from the pond together with a diversion of run-off water from an adjoining area will be utilized to flood-irrigate this grass. A spreader system of dikes has been installed to spread the water over the grass. Plans have also been made for planting a few fruit trees above the dikes to provide fruit for home use. Any surplus water from this spreader system is diverted on to grassland which has been contour furrowed; this is done in order to utilize every drop of water. Diversion of water from this draw is also preventing further development of a deep gully that has been eating up the draw from below and eventually would have destroyed the meadow. The total cost to the farmer for this facility, which includes the well and windmill, dam, and all other work described, is $940; he agreed to repay this sum within 10 years. The useful life of the facility is estimated at 20 years or more. Thus it is possible through planning to take advantage of all natural resources, that a simple windmill installation can be used as a means of completely reorganizing and rehabilitating a unit, to make it a paying enterprise.

In both of the examples just described a conservation plan and a farm- and home-management plan were worked out in addition to the structural work just described. These plans called for the application of soil- and moisture-conservation practices, improved land use, and an adequate production program.

Thirteen families inhabit the Sublett Valley, a narrow strip of land about 7 miles long and ½ mile wide, in southern Idaho in an isolated community that derives the major part of its livelihood from the livestock industry. Rehabilitation of their irrigation district, through which water is obtained for the production of stock feed, is typical of numbers of similar possible developments under the water-facilities program in the western United States.

The project will consist of reconstruction of the storage dam that serves the 13 farms (fig. 3), drilling of several wells for winter stock water, and general reconditioning of the irrigation distributing system.

Sublett Dam, at the upper end of the valley, was constructed in 1912 for irrigation water storage. It is 37 feet high and 570 feet long, with a capacity of 1,490 acre-feet. The dam has no overflow spillway, so that it has been necessary to control storage through a 3-foot circular concrete conduit. As there were only two wells in the valley proper the conduit was left partly open during the winter months to make stock water available for the ranchers. This has resulted in reduced winter storage. The reservoir storage and natural creek flow during the irrigation season were sufficient to irrigate all of 645 acres and partly irrigate 272 acres. Including 552 acres of additional irrigable land for which there was no water, a total of 1,469 acres is available in the valley for irrigation.

Upon completion of subsurface investigations and location of sufficient fill material the engineering design was drafted to include the following items:

1. Increase of 11 feet in height of the present dam, which would increase the storage 900 acre-feet. (This, with stream flow, is adequate to irrigate the entire 1,469 acres.)

2. Construction of new outlet conduit pipe with new control gate. (The old conduit had been fractured due to fill settlement.)

3. Construction of an overflow spillway through a ridge southeast of the dam.

4. Placement of an impervious blanket around the south abutment of the dam to reduce seepage loss.

5. Placement of two cut-off trenches under the new fill.

6. Construction of a system of drains under the downstream toe of the dam.

Plans were then completed for the drilling of nine combination stock and domestic water wells, and for revisions in the irrigation distribution system to include (1) water-measuring devices, (2) diversion dams and divider boxes, (3) enlargement and realinement of present ditches, (4) installation of individual farm turnouts, and (5) revision of the irrigation systems on the farms.

In conjunction with the structural program a plan of conservation operations was written to establish a long-time better land-use program for all lands to be

(Continued on p. 195)

OUR DRAINAGE PROBLEMS[1]

By JOHN G. SUTTON[2]

FEW people realize that such a large amount of our high-grade agricultural land is dependent upon drainage. Forty-four percent of the land area of Indiana is in organized drainage enterprises. A large portion of the northwest quarter of Ohio, formerly called the Black Swamp, has been drained and now constitutes the most productive agricultural area of the State. The extent of drains required is indicated by the fact that Wood County, lying in the midst of the Black Swamp area, has 2,350 miles of public drains.

In 1930 the census of the United States reported 84,408,093 acres of land included in organized drainage enterprises. Almost all these enterprises were formed for the construction of public drainage works and structures in accordance with the State laws, and private drainage enterprises less than 500 acres in size were not included. This acreage represents approximately 4.4 percent of the total area of the United States, or the combined areas of Illinois, Indiana, and Ohio. Table 1 shows the distribution of these drainage works by States, and the drainage enterprises in the eastern part of the United States may be located by referring to the accompanying map.

The rate of development of drainage enterprises as taken from the 1930 census is shown in table 2. Approximately 60 percent of the land in enterprises and 63 percent of the invested capital is in drainage projects organized during the 15-year period, 1905 to 1919. The average cost per acre was considerably more from 1915 to 1924, inclusive, than during other periods.

The above discussion relates to organized drainage enterprises. Such enterprises are essential and have been provided where physical land problems necessitated group action rather than individual action or action through mutual agreement. In addition to public drains the drainage of individual farms by means of tiles and open drains is necessary for a large proportion of our flatter lands, although there are no accurate figures to indicate the total extent or cost of private drainage. According to the 1930 census

[1] On July 1, 1939, the drainage and irrigation activities of the Department of Agriculture that are related to the land, including the C. C. C. drainage camps, were transferred to the Soil Conservation Service.

[2] Head, drainage and irrigation section, engineering division, Soil Conservation Service, Washington, D. C.

TABLE 1.—*Summary of drainage work of organized drainage enterprises by States (From United States drainage census of 1930)*

State	Land in enterprise	Improved land in enterprise	Length of ditches	Tile drains	Levees	Pumping plants	Capital invested
	Acres	*Acres*	*Miles*	*Miles*	*Miles*	*Horsepower*	*Dollars*
Ohio	8, 165, 494	7, 604, 274	25, 048	9, 371	0	25	36, 836, 449
Indiana	10, 214, 014	9, 361, 457	20, 787	10, 439	132	166	54, 110, 854
Illinois	5, 032, 682	4, 745, 840	5, 996	3, 826	1, 108	18, 658	75, 048, 548
Michigan	9, 180, 851	7, 663, 256	17, 189	3, 490	35	275	37, 677, 084
Minnesota	11, 474, 683	7, 396, 575	14, 478	9, 451	150	75	64, 139, 641
Iowa	6, 137, 649	5, 961, 454	4, 800	13, 382	113	4, 625	77, 478, 893
Missouri	3, 150, 022	2, 309, 267	4, 961	123	931	2, 533	47, 340, 174
North Dakota	1, 094, 142	1, 075, 259	818	10	0	0	3, 148, 919
Florida	5, 954, 934	783, 033	5, 113	0	718	5, 065	45, 487, 795
Mississippi	2, 988, 496	1, 950, 356	4, 022	44	228	370	23, 601, 443
Arkansas	4, 631, 155	2, 614, 427	4, 974	0	202	515	37, 532, 575
Louisiana	3, 655, 483	2, 267, 737	7, 701	2	576	6, 495	20, 752, 645
Texas	2, 833, 356	2, 011, 044	3, 662	9	216	510	12, 002, 949
California	2, 233, 714	2, 007, 987	4, 606	486	1, 390	41, 748	66, 451, 698
Other States	7, 661, 418	5, 762, 115	14, 519	4, 399	740	18, 687	79, 123, 213
Total of United States	84, 408, 093	63, 514, 081	138, 674	55, 032	6, 539	99, 747	680, 732, 880

TABLE 2.—*Rate of organization of drainage enterprises*

Date of organization	Area, all enterprises	Area overlapped	Additional land	Ratio to total land	Capital invested, all enterprises	Average investment per acre
	Acres	*Acres*	*Acres*	*Percent*	*Dollars*	*Dollars*
Before 1870	1, 056, 844	137, 727	919, 117	1. 1	1, 263, 389	1. 20
1870–1879	3, 480, 915	963, 973	2, 516, 942	3. 0	11, 317, 896	3. 25
1880–1889	9, 549, 227	3, 496, 420	6, 052, 807	7. 2	28, 035, 384	2. 94
1890–1899	11, 265, 052	5, 307, 549	5, 957, 503	7. 0	32, 838, 911	2. 92
1900–1904	12, 380, 936	4, 715, 113	7, 665, 823	9. 1	34, 139, 656	2. 76
1905–1909	23, 862, 554	5, 534, 537	18, 328, 017	21. 7	111, 612, 254	4. 68
1910–1914	22, 331, 693	5, 883, 316	16, 448, 377	19. 5	125, 953, 183	5. 64
1915–1919	23, 422, 034	7, 619, 132	15, 802, 902	18. 7	190, 583, 008	8. 14
1920–1924	12, 735, 739	5, 307, 560	7, 428, 179	8. 8	102, 976, 838	8. 09
1925–1929	8, 410, 084	5, 121, 658	3, 288, 426	3. 9	42, 012, 361	5. 00
Total, all enterprises	128, 495, 078	44, 086, 985	84, 408, 093	100. 0	680, 732, 880	5. 29

650,172 farms, totaling 44,523,685 acres, reported private drainage, but the census report states that these figures were too low, which undoubtedly is true.

During the decade, 1910 to 1919, lands that could be cheaply drained were becoming scarce and many high-cost reclamation projects were undertaken. For example, many lands requiring levees and pumps in addition to the interior drainage system were drained; these projects required a high bond cost per acre and often too little time was allowed for investigations and planning. Some of these projects were abandoned, but most of them drained good lands and are still operating. Some projects paid their indebtedness in full. Many projects defaulted on their outstanding indebtedness, and these defaults were so extensive that in 1933 the Reconstruction Finance Corporation was authorized to refinance drainage enterprises in financial distress. This agency's latest report shows that, on an outstanding indebtedness of over 80 million dollars, loans to the extent of over 34 million dollars have been authorized for refinancing. More than 69,000 farms were benefited and the average savings on annual charges were about 75 percent.

In considering the large areas of lands in drainage enterprises the thought may occur to some that the totals include some lands which should not have been drained. This is true because there are areas of considerable size, particularly those in northern Minnesota and the Florida Everglades, which have not proved adaptable to agriculture under present conditions. Outside these two areas it is doubtful whether 3 percent of the drainage enterprises based on total area would now be classed as submarginal by comprehensive land-use surveys, providing the land had proper drainage treatment. This does not mean that all of the remaining 97 percent has been profitable to the organization, but it does mean that the drainage has reclaimed wet lands which now furnish livelihood to farmers who should be able to keep the project alive.

Projects that could be completed at reasonably low cost have been generally successful, providing they had good soils as a basic resource and effective drainage was secured. A few enterprises have been undertaken which drained principally sand, gravel, peat, or other unproductive soils. These mistakes could have been avoided by careful soil investigations before undertaking the projects. Through faulty design or construction some projects did not render effective drainage. The correction of such difficulties constitutes an important drainage problem.

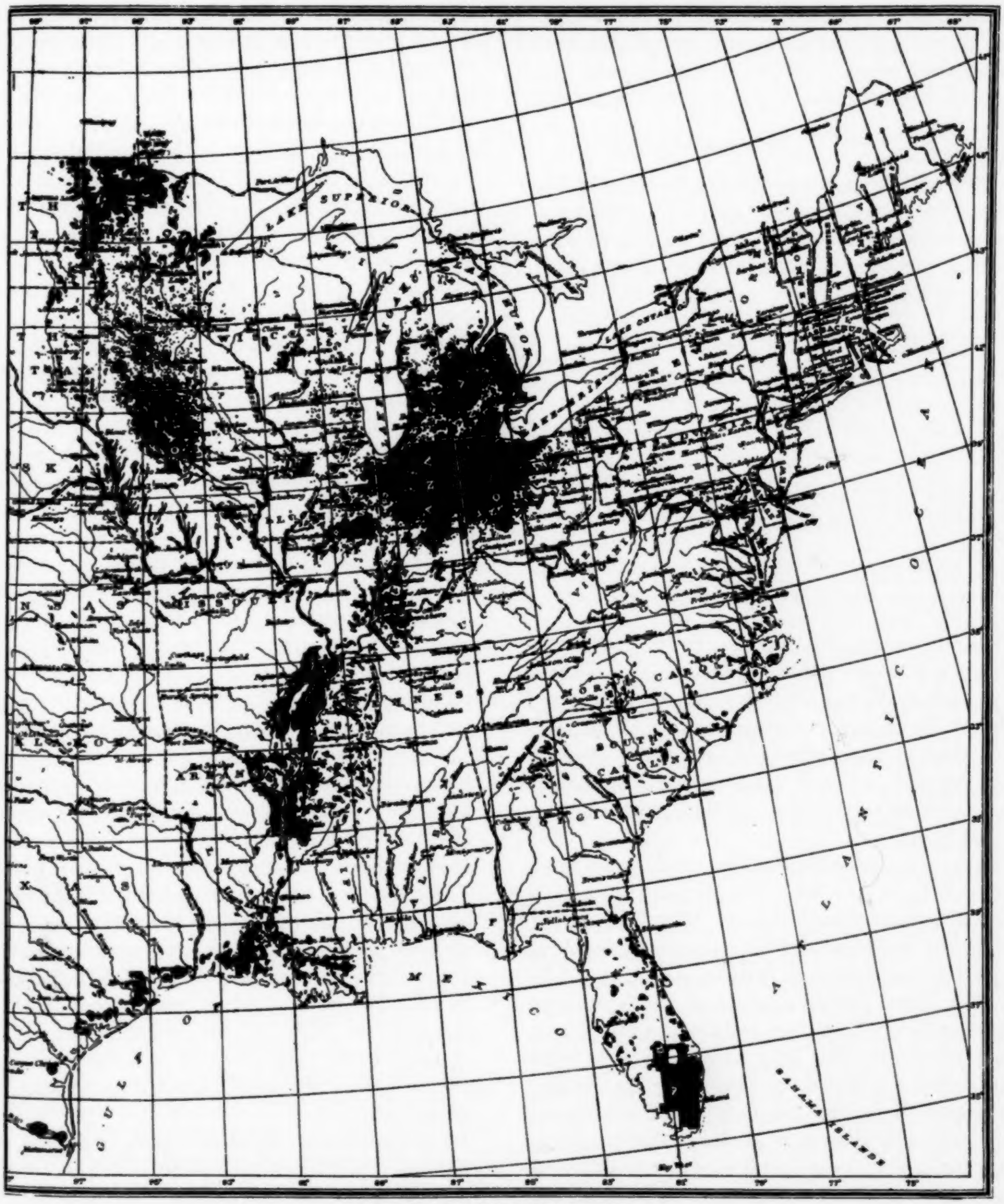
Some drainage projects, unfortunately, were undertaken without regard to proper wildlife programs for the immediate area. It is now generally recognized that conservation of wildlife is one of the essentials of a good land-use program. Some marsh areas should be devoted to this purpose, and it is not in accordance with good land use to drain the last acre of marsh land in any section. Through the work of the Biological Survey, State conservation departments and other agencies, considerable land is being placed under public control to solve the problems met in the conservation of wildlife.

The Maintenance Problem

Aside from all questionable areas, there still remain tremendous areas of good agricultural lands that are dependent upon drainage. These are the lands with which the Service is primarily concerned. Probably the most important of our problems in relation to these lands is to secure continuous maintenance of established drainage enterprises. There is much room for progress in financial, organizational, and physical aspects of maintenance. The maintenance generally has not been adequate; ditches have been dug and allowed to grow up in trees and brush and to silt up. Without maintenance this would continue in most communities until enough landowners were damaged, through low crop yields and loss of crops, to secure wide local support for new assessments. Some of the landowners would normally go bankrupt in the process because of unfavorable locations of their lands. Owners of the lands having fair natural drainage would tend to resist additional expenditures until rising water levels affected them. The C. C. C. drainage camps, many W. P. A. projects, and other State and Government activities have been undertaken in recognition of the necessity of proper maintenance of public drains.

The financial aspects of the problem cannot be overlooked, and some State drainage laws could well be revised to facilitate maintenance work. To perform a maintenance operation, some States require assessments, court approvals, legal and engineering procedure, almost as complicated and expensive to the farmer as the organization and establishment of a new drain. In other States the responsibility is placed on local elected officers and often they postpone necessary maintenance work in response to local complaints against levying additional taxes. It has been found that more adequate local maintenance is given in those drainage enterprises where the volume of annual maintenance justifies continuous employment of a person or staff whose sole responsibility is the maintenance work. In many instances the expense of maintenance, together with the retirement of the original

Location of land in Drainage Enterprises in the Eastern United States



Taken from the 1930 U.S. Drainage Census

bonds, has been so high that subsequent taxes could not be paid. This encouraged postponement of maintenance work. In many enterprises the landowners do not appreciate the necessity of maintenance and extensive educational work is necessary. In other enterprises large acreages of idle lands have been one of the principal factors causing defaults and neglected maintenance. Productive lands must be utilized to secure self-supporting enterprises.

Many of our present problems are strictly technical in character and involve some fault in design or construction. Difficulties of this kind occur so frequently

that it is pertinent to point out the necessity of conducting technical phases of drainage operations under the supervision of engineers thoroughly familiar with the standard practices covered in the numerous textbooks on drainage and experienced in such operations.

The C. C. C. Drainage Camps

In 1935 the Bureau of Agricultural Engineering was allotted 46 C. C. C. camps to work on the rehabilitation and reconstruction of existing drainage improvements of which seven camps have been discontinued.

TABLE 3.—*Location of original and present drainage camps* [1]

State	Original	Present
Dalaware	2	2
Maryland	3	4
Ohio	9	6
Indiana	8	6
Kentucky	2	2
Illinois	6	5
Iowa	5	4
Missouri	6	4
Louisiana	5	5
Michigan	....	1
Total	46	39

[1] One additional drainage camp is scheduled for Mississippi, Apr. 1, 1940.

The primary objective of the work of C. C. C. drainage camps is to rehabilitate the drainage improvements of organized drainage districts, county drains, and other public ditches or drainage works constructed or maintained in accordance with State laws. Another objective is to establish demonstrational projects to serve as examples of improved design, construction, or maintenance.

To anyone not familiar with the condition of public drains in 1935, it is difficult to picture their general condition after years of neglect. Very little maintenance work had been done for many years prior to the depression, and practically none during the years 1930 to 1935. Most ditches had become completely overgrown with brush and trees and the capacity of many neglected channels had fallen to one-half or even one-fourth of that necessary for proper drainage and flood protection. Tile lines had been neglected also, and tile had become filled up or broken so that many lines were ineffective. Levees were overgrown with brush and vegetation and often were so weakened by groundhogs and other rodents that they could not withstand a minor flood.

The work of C. C. C. projects has included clearing vegetation from drains, excavating ditches, clearing and repairing levees, cleaning tile lines, and repairing or improving other drainage structures such as pumping plants, headwalls, and ditch structures. The work on unimproved creeks, rivers, and other drainage channels is limited to that required to furnish a satisfactory outlet and to protect works constructed by an organized drainage enterprise. All camp work is confined to projects benefiting lands which are unquestionably of high agricultural value when properly drained. Projects that would bring additional land in cultivation, keep in cultivation lands of poor fertility or of submarginal character, or reclaim new farm units, have not been undertaken. No work has been done on private drains.

Wherever possible, the camps have encouraged construction of complete demonstration jobs. A complete ditch job includes clearing, excavating to grade, construction of necessary structures to prevent and control silting, seeding the side slopes to stabilize banks, and treatment of spoil banks. Ditches with 2 to 1 and, in a few instances, 3 to 1 side slopes have been built as experiments and demonstrations. These flatter slopes have been seeded to grass so that they could be pastured or mowed. Leveling spoil banks to permit cultivation or pasturing to the edges of the ditches has been encouraged where it was apparent that this was proper use for the land involved. The drainage camps have undertaken the rehabilitation of numerous tile drains which failed as a result of improper construction, clogging, or damage. Many tile outlet structures also were repaired or reconstructed. The construction of levees to proper grade, and with sufficiently flat slopes to be safe, has been encouraged together with seeding, pasturing, and fencing of levees, as there is little doubt that a well-pastured sod furnishes the best vegetative covering for a levee.

The drainage camps have secured substantial cooperation from local drainage enterprises on nearly all work projects. The total cooperation secured by camps listed in table 4 averaged $2,307 per camp month. This investment encourages local people to accept responsibility, to take a greater interest in the drainage works, and to continue maintenance as a regular activity after the C. C. C. drainage camps are withdrawn.

The readiness of landowners, drainage officials, and drainage organizations to cooperate in this undertaking has been one of the chief factors in the success of the work and has enabled the camps to accomplish a much greater volume of work and to undertake more difficult jobs than otherwise would have been the case. The chief contribution of the Government has been the labor of the C. C. C. enrollees and one or two small draglines per camp to facilitate organization and

(*Continued on p. 194*)

RESEARCH PROBLEMS IN CONSERVATION ENGINEERING

By MARK L. NICHOLS [1]

THE primary objective of the Soil Conservation Service is to develop a sound and practical program of soil and water conservation and put that program into effect on the farm lands of the United States. This is rather a large order. In the first place, it involves almost everything in agriculture, and this means that we must consider not only the physical problems, which are sufficiently complicated in themselves, but the social, political, and economic problems as well. Naturally, there is need for great variety of skills and techniques and for people with a wide range of training and experience.

In my opinion, putting the various elements together into a practical farming program, instrumenting them with methods and equipment and placing them into operation on the land, is engineering. There are those who insist that conservation is primarily good agronomy and others who insist that the basic consideration is soils. There is no doubt in my mind but that they are both right, nor do such claims conflict with the statement that the entire program is agricultural engineering in the broader sense. In this article we shall disregard the divisions of science set up for administrative reasons in the Department of Agriculture and State institutions, and discuss engineering problems in conservation as farm problems that involve engineering, but certainly not to the exclusion of other branches of agricultural science. For convenience of discussion, the subject is broken down into two parts conforming in a general way with common engineering subject-matter classification.

Machinery Problems

Regardless of the fundamental soundness of the conservation program, it cannot be put over with the farmer unless the methods of application are worked out to a point where the farmer can be shown by demonstration exactly what to do and how to do it. In general, any program of conservation of cultivated or bare land consists of parts or combinations of the following practices: (1) Interception by channels or levees of concentrated waters flowing across the area to be conserved; (2) maximum surface protection of the area by good agronomic practice, usually consisting of proper rotations, maintenance of a high level of organic matter, and strip cropping to disperse concentration and to permit good tillage practices with proper row arrangement; (3) means to conduct excess rainfall from the land with the minimum of erosion; (4) removal from cultivation of areas too steep for cultivation under general farming practices—such land can be used for permanent pasture or woodlots.

The second consideration is of primary importance in machinery studies. Probably this can best be illustrated by a specific example: In the area around Presque Isle, Maine, the chief industry is the production of potatoes. Very high yields are common in this area and although there is only a short growing season the climate seems particularly adapted to the production of this crop. The distance to the market, however, is such that the shipping costs are high. These conditions naturally result in a broad development of this industry through extensive methods of agriculture using power machinery. Under these conditions, the potato land is fallowed or plowed up in the fall and left bare during the winter and this results in extensive soil loss through the melting of snow. Large-scale operation for a short period of time naturally requires large machinery—two-row planters and diggers and spray rigs handling many rows at the same time. Under this system the rows have been run up and down hills, and summer storms remove vast quantities of soil from the fields.

Obviously, here is an engineering research problem of major importance, and upon its solution depends the permanent welfare of a large area in northern Maine. I am informed that the first device used to solve the problem was that of putting the potato rows on the contour. The effect of this was such that moisture conditions became so changed as to result in heavy loss of potatoes in the field. Moreover, because of the slope there were serious complications in machinery operation due to side slippage. It seems obvious that there is some mean between the contour and the up-and-down-hill arrangement of rows that can be worked out to allow the minimum of erosion within the moisture tolerance of the crop. To meet this there must probably be some modification either in the use or in the present design of equipment. In all probability, if long rows are to be used as conditions indicate that they are necessary, interception of run-off

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must be provided, either by drainage-type terraces or by some other device that will not interfere too seriously with the use of large equipment. Such development would be of great benefit not only to the Aroostook County area but also to other areas throughout the whole Northeast. In this connection, the problem of handling the waters of melting snows to prevent erosion is being attacked by the use of what we may call for want of a better term, a "snow terrace" superimposed upon the ordinary terrace system to prevent plugging with slush during thaws.

Problems in the use of machinery in conservation are of course not limited to the potato areas of the Northeast. American agriculture has been keyed to the maximum production per man of necessary commodities by large machinery. In some instances extensive use of this power has resulted in an exploitive type of agriculture that has brought about the destruction of the land itself. The most outstanding example is the Dust Bowl. Some find fault with the tractor, and power farming itself, as a cause; and while this in some respects is justified, it is the abuse of the method rather than any fundamental wrong in it that has caused the destruction. One might as well find fault with good food because many people injure themselves by overeating. In my opinion, however, it is of basic importance that the agricultural engineer direct his energies toward the development of methods by which this equipment can be used to promote conservation. The power itself can be made to become an instrument of conservation if properly directed.

Under the old system large quantities of roughage were produced to feed horses and mules for power. The reduction of this food requirement naturally has increased the amount of land available for salable products and undoubtedly it has had an effect upon the markets as well as upon erosion. It is a matter of considerable importance for us to consider the use of this equipment in producing cover crops and feed crops for other types of animals and for soil building.

Most of this engineering experimentation must be coupled with and based upon new soil-building developments and agronomic practices. We know that favorable soil structure and resistance to erosion are closely related to the organic-matter content of the soil and its microbiological associations. For example, material reduction in erosion can be attained by the use of mulches, and it has been the practice for some time in the far West to use a trashy fallow to prevent wind erosion. This use of plant residues to prevent erosion involves, for practical application, and under present conditions, the employment of machines. One farmer in the far West has developed a machine that leaves practically all the straw on the surface, tied down just enough by the soil so that the wind does not blow it. Another farmer in Georgia has for a number of years successfully maintained good production in cotton without plowing; he leaves the plant material and organic matter on the surface, in balks between the cotton rows. Several State experimental stations are now engaged in research involving the retaining of plant cover and other crop residues at or in the surface, in such a way as to leave an effective mulch during most of the season.

The engineer has a very important and practical role in such developments. Our position in the Federal or State service is such that we must try to determine what needs to be done and to cooperate with manufacturers of equipment to find how the job can be accomplished by machines. We are working on the principles upon which designs must be based, and we leave the design to the manufacturer who must consider the many and varied problems of machine production. In the vast majority of cases, however, the ends we desire can be accomplished with machines now in production. For example, one of the main terracing problems is maintenance of the terrace channel. Experience shows that this can be accomplished efficiently as part of the regular farming procedure by varying the methods of plowing and using perhaps one or two special operations to keep the channel clear. The development and application of strip cropping systems—an important and practical conservation operation—generally can be handled with present equipment; but the width and length of strips must be adjusted to the use of the equipment the farmer now possesses. The entire machinery use must be studied and field practices varied if efficiency is to be maintained with various crop combinations.

Hydrologic Problems

In the Eastern States hydrology has not received much attention as an agricultural problem except as it applies to drainage. A few pioneers have done some work toward collecting the run-off data from small areas for use in the design of outlet ditches or terrace outlets; but there is a decided lack of information in this particular field. Up to a few years ago only two or three experimental stations and the Soil Conservation Service had data from experimental plots and a few small watersheds. In the field, conservation engineers in general were forced to fall back on guesses based on data gathered from storm sewer discharge.

There is a considerable volume of data on run-off of rather flat lands, gathered as a result of drainage experience, but this cannot be applied to steep lands where soil conservation is the chief problem. At the present, the Army and interested bureaus of the Department of Agriculture are engaged in getting together the best information available for flood-control purposes. The Forest Service has considerable data from forested areas, gathered during the past few years, but their work can be said only to be well under way, and their information cannot be applied generally to cultivated areas. Power companies, the Geological Survey, the Army, and other agencies have data from large watersheds.

In general the leading authorities on hydrology are not in agreement as to the effect of land use on run-off when it comes to quantitative evaluations of specific practices, although there are few who still believe that this is not a most important consideration. Congress has recognized the importance of land use in controlling run-off, by making the Secretary of Agriculture jointly responsible with the Secretary of War for flood control.

The Department of Agriculture and a number of State experimental stations are now seriously engaged in starting studies to determine specifically what can be done as regards run-off through the use of various land-use practices. In general these studies are directed at specific practices intended to use the soil and underlying strata (1) as a storage to regulate stream flow and (2) to reduce the drought hazard as far as possible by utilizing all the rainfall available in drought periods.

Many studies are being initiated on methods of inducing greater infiltration of water. Usually these are based on combinations of agronomic practices such as keeping up good covers and incorporating large quantities of organic matter in the surface of the soil (mulching) and upon engineering practices such as terracing or contour furrowing.

If we limit the term infiltration to the act of water going into the soil and entirely dependent upon surface conditions, we must also consider the permeability of the lower soil horizons and their maximum transmission capacity (defined as the upper limit of permeability). Many studies of permeability and transmission capacity are under way. Such studies must be made for most of the soils of the country, or indices of transmission capacity must be found and proved. Fortunately it appears that transmission capacity is frequently, if not generally, in excess of the infiltration rate, so that studies of methods of increasing infiltration are promising of practical results. If we find methods of keeping the surface pores or channels open by protection from slacking, packing by rain or poor tillage, or other packing or clogging, we can put very great quantities of water into the soil. It is recognized, of course, that various kinds and depths of soil and substrata limit this reservoir capacity; but in a majority of conditions throughout the United States the capacity, considering rainfall and its distribution throughout the season, is sufficient to be a most important factor in flood-control and water conservation. It must also be recognized that surface and subsurface conditions are always changing and that capacity in some soils, as well as permeability, may be completely changed by swelling or wetting, destruction of channels formed by roots, earthworms, etc.

There are many problems of a physical nature that are still practically untouched except in a very general way. Some of these are as follows: The retardation of flow by various vegetations; the effect of such surface detention on infiltration; the rate and energy of flow where surface tension phenomena play an important part, as in overland flow; the effect of slope and surface roughness coefficients; and so on, through a whole category of unknowns.

When one considers, as cause and effect, the general relationship between these energy-of-flow reactions and the resistance to erosion of the soil; and when one carries these studies to the point where practical results can be obtained by (1) reducing quantity of rainfall excess and consequently the total kinetic energy of the water through shortening slope length (i. e., interception with terraces or other channels) and (2) decreasing the erodibility by including organic matter; and when one realizes here that organic matter induces microbiological action, binding the soil together with mycelium and "bacterial mucilage," and reinforcing the entire surface and subsurface structure with plant roots and stems and their associated mycorrhiza; and when one is cognizant, at all times, of the constantly changing nature of the entire system set-up with season and exposure, with human and animal interference, and that over all and behind the present looms the effect of past history with resultant levels of fertility and natural plant associations and successions—surely there can be no question as to the need for research and no need to search for studies. The only question is where to start unraveling such a tangled thread.

There are numerous other problems of importance that can only be touched upon here, but for the pur-

(*Continued on p. 194*)

SOME PRELIMINARY RESULTS FROM RUN-OFF STUDIES ON DEMONSTRATION PROJECTS

By D. B. KRIMGOLD,[1] JOHN L. WEBER,[2] AND N. E. MINSHALL [3]

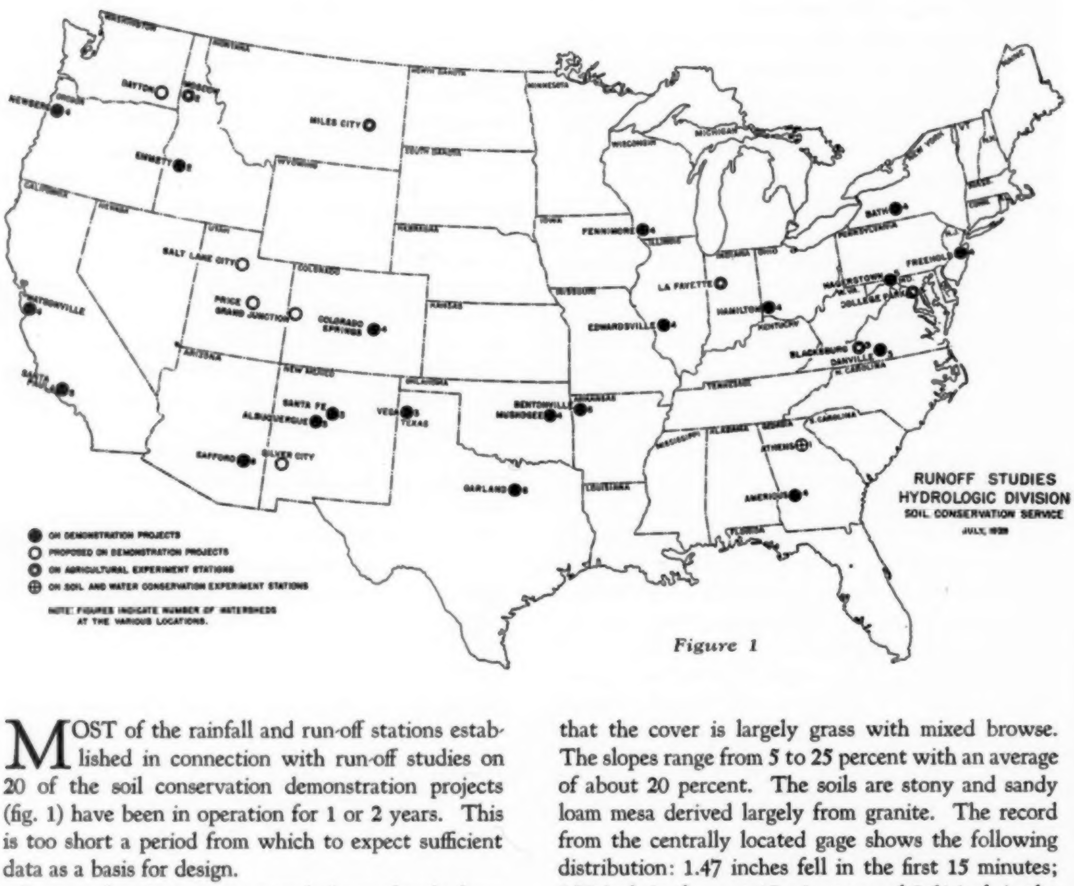

Figure 1

MOST of the rainfall and run-off stations established in connection with run-off studies on 20 of the soil conservation demonstration projects (fig. 1) have been in operation for 1 or 2 years. This is too short a period from which to expect sufficient data as a basis for design.

Some rather interesting records have already been obtained, however, on a number of the projects. For example, J. H. Dorroh, Jr., line project leader, reported an unusual rainfall record secured by J. S. Watkins, observer, on the Safford, Ariz., project. This rain of 2.84 inches in 85 minutes was recorded by three recording rain gages on a 380-acre watershed near Safford on August 2, 1939. This drainage basin is entirely in range land, and preliminary surveys indicate that the cover is largely grass with mixed browse. The slopes range from 5 to 25 percent with an average of about 20 percent. The soils are stony and sandy loam mesa derived largely from granite. The record from the centrally located gage shows the following distribution: 1.47 inches fell in the first 15 minutes; 0.73 inch in the next 15 minutes; and 0.64 inch in the remaining 55 minutes. It also shows that the maximum amount that fell in any 15-minute period was 1.60 inches. This greatly exceeds the 15-minute rainfall to be expected once in 100 years in this locality, according to Yarnell.[4]

An extrapolation of the data given by Yarnell indicates that the expectancy of this 15-minute amount is somewhere in the neighborhood of once in 500 years. This of course gives only a rough idea of the expectancy. It must also be remembered that the data given in the bulletin are probably based on records from Phoenix and Flagstaff, Ariz., El Paso, Tex., and possibly Roswell, N. Mex., none of which could truly represent the rainfall in the foothills of the Graham

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[4] David L. Yarnell: Rainfall-Intensity-Frequency Data. U. S. Department of Agriculture Miscellaneous Publication No. 204.

Mountains near Safford, Ariz. The run-off resulting from this rain cannot be accurately compiled until the necessary maps are available. A preliminary examination of the record indicates, however, that the maximum rate exceeded 900 c. f. s.[5], which is 2.37 c. f. s. per acre or 1,500 c. f. s. per square mile—a considerable rate for this size of drainage basin. Without a complete discussion of the characteristics of the watershed and of antecedent conditions, the above run-off values do not mean much; they are, however, an indication of the type of data that already have been obtained.

A large number of records were obtained on other projects, notably Freehold, N. J., Hagerstown, Md., and Bath, N. Y., in Region 1, where the rainfall and run-off stations have been in operation longer than on any of the other projects. Most of the data, including those from Region 1, cannot be made available because the necessary surveys and maps have not been completed. But as a result of the interest of regional and project offices in Regions 5 and 6 and the untiring efforts of Messrs. R. P. Weeber and H. K. Rouse who were assigned to the studies on the Edwardsville, Ill., and Colorado Springs, Colo., projects, respectively, all the preliminary work has been completed and the records from these projects are in very good shape. For this reason the results from these two projects are discussed in this article.

The rain of August 10, 1938, on watershed W–IV at Colorado Springs is worthy of note. The permanent characteristics of this 35.6-acre watershed are shown on the soil and topographic map (fig. 2). The land has never been cultivated and represents foothill inceptive type of grassland. The cover and tillage map for the year of 1938 (not shown) gives the following description of cover conditions as of July 18, 1938:

Type area No. 1 (33.2 acres):

- Blue grama: Density 6 percent; average height 2 inches.
- Other short grasses: Density 2 percent; average height 4 inches.
- Club moss: Density 6 percent.
- Forbs and weeds: Density 2 percent; average height 8 inches.

Type area No. 2 (2.4 acres along watercourses):

- Blue grama: Density 33 percent; average height 4 inches.
- Sedges and rushes: Density 0.5 percent; average height 5 inches.
- Forbs and weeds: Density 1 percent; average height 10 inches.

The records from two recording rainfall stations on this watershed show a total of 1.91 inches in 63 minutes. Of this amount 0.67 inch fell in the first 15 minutes, 0.99 inch in the next 15 minutes, and 0.25 inch in the remaining 33 minutes. The 0.99 inch in 15 minutes exceeds the 15-minute rainfall to be expected once in 10 years and is nearly equal to that to be expected once in 25 years, according to United States Department of Agriculture Miscellaneous Publication No. 204.

The run-off resulting from this rain began 16 minutes after the beginning of rainfall. The maximum rate of 87 c. f. s. was reached 13 minutes after the beginning of run-off. The peak rate of 87 c. f. s. lasted for only a fraction of a minute. However, a rate in excess of 43 c. f. s. persisted for 15 minutes. Since in the Great Plains total yields are as important if not more so than maximum rates, it may be well to point out that the total run-off amounted to only 0.67 inch or 2 acre-feet. Sixty-five percent of the total rainfall was thus retained on the watershed. This is significant in view of the rather high intensities of rainfall. It indicates a rather high rate at which the water was entering the soil during this storm. The characteristics of the soil, as shown by the column descriptions in figure 2, and the fact that this rain was preceded by a rain of only 0.30 inch on July 26 and 0.05 inch on July 28, may explain the larger amount of water retained.

A discussion of whether and how the "rational formula" (Q=CIA) should be used is beyond the scope of this paper. In view of the misconception which apparently still exists, however, the writers consider it advisable to point out that the run-off coefficient, C, in the rational formula is not the ratio of the total run-off to the total rainfall but is the ratio of the rate of run-off to the rate of rainfall. If one takes the so-called "time of concentration" to be the period between the time of beginning of run-off and the time of maximum rate of run-off (13 minutes in this case), the coefficient of run-off would be 0.56 or 0.61 depending on whether one uses the maximum rainfall intensity for any 13-minute period preceding the time of maximum run-off, or the intensity for the particular 13 minutes between the time of beginning of run-off and the time of maximum rate.

It was already stated that, according to United States Department of Agriculture Miscellaneous Publication No. 204, the expectancy of 0.99 inch of rain falling in 15 minutes is about once in 25 years. This expectancy may or may not hold for the maximum rate or the total amount of run-off. At the time this rain occurred the condition of the watershed was not conducive to high rates of run-off. Had the same

[5] Cubic feet per second.

rain occurred when the soil was saturated or frozen, or had the high intensities in this rain been preceded by low intensities for a fairly long period of time, much higher rates of run-off and total yields would have resulted. A study of past records may show, however, that the probability of such a rain occurring when the soil is frozen or saturated is remote. It is also possible that in this locality where heavy precipitation results from convectional storms, high intensities always occur at the beginning of the rain. In view of the above it is not possible to arrive at the expectancy of this run-off without a study of past records of rainfall with particular reference to the time of the year, antecedent rainfall and temperatures, as well as intensity distribution. After such a study is made the probable expectancy of this run-off may be determined and the maximum rates of run-off in cubic feet per second per acre obtained from this watershed may be recommended for use in estimating run-off from watersheds with similar characteristics.

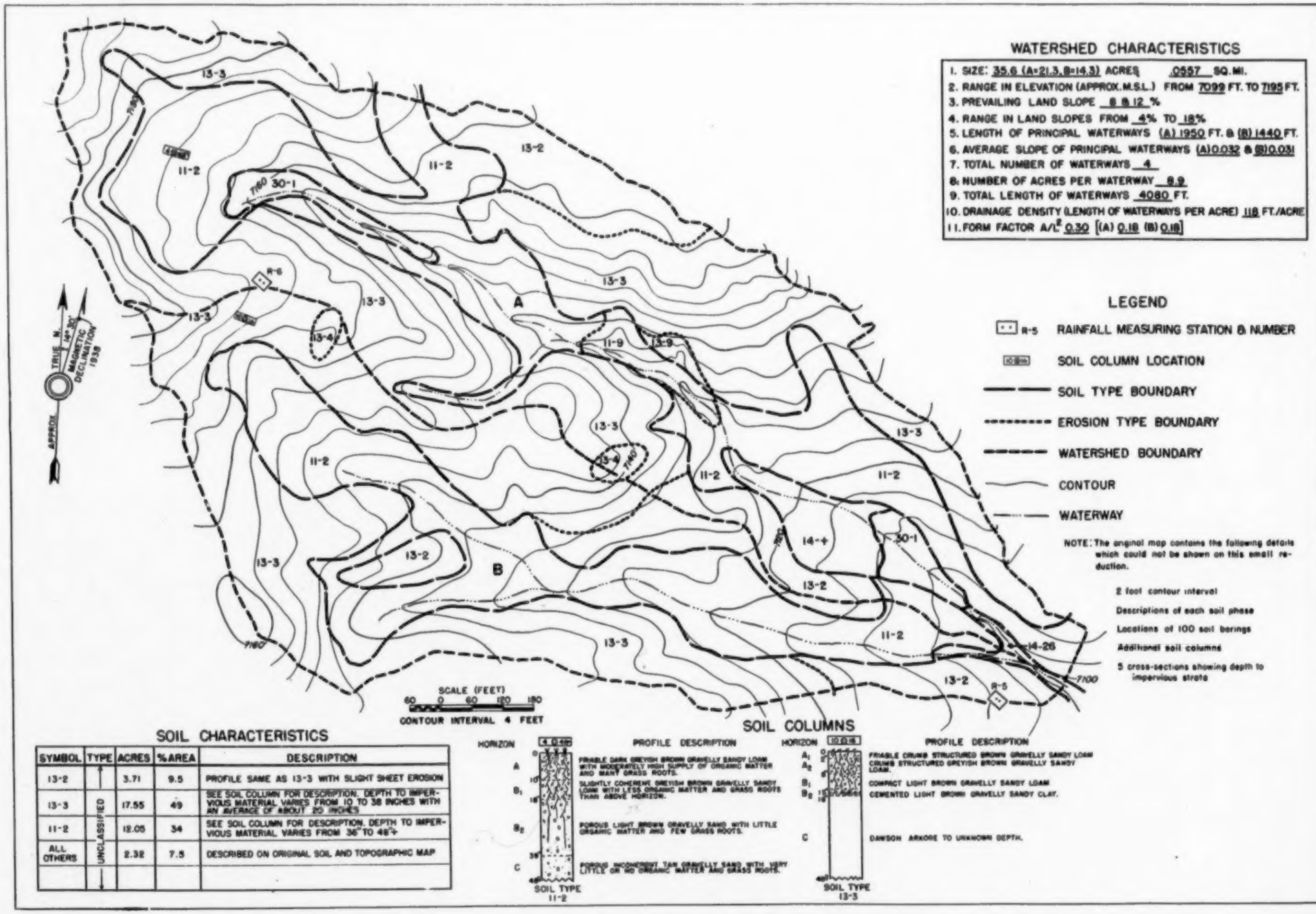
Of the run-off records secured on the Edwardsville project, those of March 30 and July 17, 1938, are the most outstanding. Other records secured in the summer of 1939 offer interesting comparisons. Maps similar to figure 2, as well as cover and tillage maps for the run-off periods mentioned above, are available for the four watersheds on this project. Lack of space does not permit including them in this paper. An attempt will be made, therefore, to outline briefly the characteristics of these watersheds before the records are discussed.

Watershed W–I is a nearly level, rotation-cropped area of 27.22 acres located on the James Love farm 5 miles northeast of Edwardsville. The area is fan-shaped with two main tributaries and with a difference in elevation of 20 feet from the measuring weir to the highest point in the watershed. Approximately 75 percent of the area has a slope of less than 2 percent while the maximum slope for a small area near the weir is 10 percent. The main soil type is Bogota silt loam, with small areas of Alma silt loam and Drury fine sandy loam, all of which have a fairly impervious subsoil. This watershed is divided into three fields. In March 1938, field 1 (7.5 acres) was in corn stubble; field 2 (14 acres), in bean stubble; field 3 (4.5 acres), in wheat about 3 inches high. The remaining 1.22 acres were in pasture. During the summer of 1938 the cover consisted of corn in field 1, small grain seeded to alfalfa in field 2, wheat seeded to sweetclover in field 3, and pasture on the remaining 1.22 acres. The crops for 1939 were: wheat seeded to sweetclover in field 1, alfalfa in field 2, corn in field 3, and pasture in the remaining 1.22 acres.

Watershed W–II is located on the William Eaton and Love estate farms a short distance from W–I. This watershed, with an area of 49.95 acres, is approximately 1½ times as long as its greatest width and has a difference in elevation from the measuring weir to the highest point in the watershed of 40 feet. The topography is rolling with slopes of 0 to 5 percent on the uplands which drop off rather abruptly into well-defined water courses. The main soil types are Bogota, Alma, and Elco silt loams all of which are quite severely eroded. Approximately 90 percent of the area is in permanent pasture and the remainder in a rotation-cropped field.

Watershed W–III consists of a 12.55-acre terraced hillside located on the Mathilda Buchta farm about 5 miles north of Edwardsville. The run-off from this area is carried by six terrace channels to an outlet channel located on one side of the area. The terraces have an average length of 1,100 feet with a total drop of 3.5 to 4.0 feet. The vertical spacing of the terraces is 5 to 7 feet. The terrace outlet is a sodded channel about 10 feet wide having a total length of 550 feet and an average slope of 6 percent. The slopes of this area vary from 3 to 15 percent with an average of 8 percent over a large part of the area. Ninety percent of the area is Alma silt loam with moderate sheet erosion. The entire area is in one crop during any year, the 1938 cover being wheat seeded to sweetclover and the 1939 cover was corn.

Watershed W–IV is 289.8 acres in size. It includes all of areas W–I and W–II previously discussed and is located on the James Love and William Love estate, and the William Eaton and Edward Halbe farms. The watershed is nearly circular in shape, with serious erosion over most of the steeper portions or about one-third of the area, and has a well-defined drainage system with two main tributaries. The upper portions of the area are quite flat, but the slopes become very abrupt near the stream channels with some of them as steep as 30 percent. The difference in elevation from the highest point in the area to the run-off measuring station is 63 feet. There are four small stock ponds in this area draining a total of approximately 20 acres. These ponds all have tile outlets and the run-off from the areas above them may or may not be contributed to the run-off at the station, depending upon the depth of water in these ponds at the time of the rain. The soils of this area are mainly Bogota, Alma, and Elco silt loams with smaller amounts of Whitson and



SOIL CHARACTERISTICS

SYMBOL	TYPE	ACRES	%AREA	DESCRIPTION
13-2	UNCLASSIFIED	3.71	9.5	PROFILE SAME AS 13-3 WITH SLIGHT SHEET EROSION
13-3		17.55	49	SEE SOIL COLUMN FOR DESCRIPTION. DEPTH TO IMPERVIOUS MATERIAL VARIES FROM 10 TO 38 INCHES WITH AN AVERAGE OF ABOUT 20 INCHES
11-2		12.05	34	SEE SOIL COLUMN FOR DESCRIPTION. DEPTH TO IMPERVIOUS MATERIAL VARIES FROM 36" TO 48"+
ALL OTHERS		2.32	7.5	DESCRIBED ON ORIGINAL SOIL AND TOPOGRAPHIC MAP

Figure 2, Soil and Topographic Map, Watershed IV, (R. & R. Ayer), Colorado Springs, Colorado.

Drury fine sandy loam. Approximately, 30 percent of the area, which includes most of the steeper portions, is in permanent pasture while the remainder is mostly rotation-cropped.

On March 30, 1938, a rain ranging from 1.58 inches on W–II to 1.85 inches on W–III occurred between about 3 a. m. and 8 a. m. This 5-hour rain produced run-off on all four watersheds. Between about 7 p. m. and 9 p. m. on the same date another rain ranging from 2.24 inches on W–I to 2.45 inches on W–III occurred on the four watersheds. A partial record of the evening rain and the resulting run-off on the several watersheds is given in the following table.

Item	W–I, 27.22 acres	W–II, 49.95 acres	W–III, 12.55 acres	W–IV 289.8 acres
1. Total rainfall....................inches...	2.24	2.30	2.45	2.37
2. Duration of rainfall..............minutes..	125	104	110	125
3. Time of beginning of rainfall (p. m.)........	6:56	7:00	6:50	6:56
4. Time of beginning of run-off (p. m.).........	7:00	7:00	6:50	6:56
5. Time of maximum rate of run-off (p. m.)..	7:40	7:34	7:11	7:44
6. Maximum rate of run-off...........c. f. s..	62.2	132.4	47.4	399
7. Maximum rate of run-off...c. f. s. per acre..	2.28	2.65	3.78	1.37
8. Time interval between beginning and peak of run-off.....................minutes..	40	34	21	48
9. Maximum amount of rainfall that fell in the intervals shown under item 8....inches..	1.55	1.52	1.39	1.86

In view of the morning rain it is safe to assume that the soil on all the watersheds was quite saturated when the evening rain occurred. The fact that the run-off resulting from the evening rain began within 4 minutes af the beginning of rain on W–I, and simultaneously with the beginning of the rain on the other three watersheds, indicates that not only was the soil saturated but practically all of the depression storage was filled at the time this rain occurred. We are, therefore, dealing with watershed conditions that are most conducive to maximum rates and amounts of run-off. The resulting maximum rates of run-off are shown in the above table.

The total run-off from W–I was computed and found to be about 2 inches which constitutes nearly 90 percent of the total rainfall. It will be noted that the maximum rate of run-off in cubic feet per second per acre was greater on W–II than on W–I although W–II is almost twice as large as W–I and 90 percent of it is in pasture while 95 percent of W–I is in cultivation. Other things being equal, one would expect a smaller rate per unit area from a larger watershed. The higher rate on W–II is no doubt due to the steeper topography and to the severe erosion. The high rate of 3.78 c. f. s. per acre from W–III is partly due to the somewhat higher total rainfall, greater rainfall intensities, and steeper slopes as well as to the size of this area.

If we assume the time intervals given under item 8 in the table to be the "times of concentration" of the various watersheds for this storm, the amounts given under item 9 would be used to determine the rainfal intensity I in the rational formula $Q=CIA$. United States Department of Agriculture Miscellaneous Publication No. 204, referred to above, does not give the expectancies occurring in the time intervals given under 8 of the table. A rough estimate of what the expectancies would be in accordance with this publication was obtained by interpolation. It was found that the expectancies on W–I, W–II, and W–IV were of the order of about once in 5 years. The expectancy on W–III was once in 10 years.

While in the case of the Colorado Springs record heretofore discussed the expectancy of the run-off may conceivably be the same as that of the rainfall, it is highly improbable that the expectancies as set forth above would apply to the Edwardsville March 30 run-off. The above mentioned publication gives the expectancy of various amounts of rainfall falling in certain intervals of time at any time of the year, but does not give the expectancies of such amounts falling in any particular month or season of the year. This again brings out the necessity of studying past rainfall records in the manner mentioned above before expectancies of run-off can be arrived at. It is quite probable, and past records no doubt show, that a rainfall of 1.55 inches in 40 minutes can be expected to occur during the summer months, once in 5 years. It is highly improbable, however, for such a rain to occur with the same frequency in March. Again, the probability of such a rain in March being almost immediately preceded by a gradual rain of more than 1.50 inches is even more remote. It is, therefore, quite possible that a further study of past records would show this run-off to be of an expectancy of once in 25 years or more.

In connection with the above discussion it will be interesting to examine some of the summer records from these watersheds. Next to the March 30, 1938, run-off rates the ones resulting from the July 17, 1938, rain were the highest thus far obtained. The total of this rain was about twice that of the evening rain of March 30, 1938, its duration was considerably longer and the intensities were generally smaller. The run-off rates resulting from this storm were less than half of the March 30, 1938, rate for W–I, W–II, and W–III and slightly more than half for W–IV. On July 16, 1939, a rain of 2.84 inches, with intensities only slightly less than those of the rain of March 30, 1938,

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Erosion-Control Lessons From Old-World Experience

IV. PRECEDENTS IN THE CONTROL OF WATERS

By W. C. LOWDERMILK [1]

PROVISIONS of the Omnibus Flood Control Act of 1936 require the Department of Agriculture to recommend and carry out approved measures for run-off and water-flow retardation and soil-erosion prevention in the interests of flood control. Of special interest to conservationists of the United States, therefore, are the fruits of 700 years of experience in England in dealing with surplus and flood waters which have ripened into an Act of Parliament.

The Land Drainage Act passed by the Parliament of Great Britain on August 1, 1930, was drafted on the basis of findings of a Royal Commission appointed in 1927 to find a solution to the confusion in the whole matter of land drainage, including flood control, and its administration. The Act authorizes the Minister of Agriculture to designate catchment areas of the main rivers as administrative units, and to set up Catchment Boards with wide powers of coordination and administration of the control and use of waters.

The Royal Commission of 1927 found a heterogeneous collection of 361 drainage authorities, exclusive of award authorities, in control of about 2,892,000 acres of land in England and Wales. Fully 4,362,000 acres of land depended on arterial drainage for their productivity, and 1,755,000 acres were in urgent need of drainage.

The confusion and conflicts of the multifarious authorities had grown out of a long experience with independent drainage boards and authorities. The first such authority was the board of officials of Romney Marsh which has been in existence for nearly 700 years.[2] This ancient authority with its laws and customs furnished a model for the Commissioners of Sewers under the Statute of Sewers in 1531. The powers of the commissioners were later codified in 1833, and again under the Land Drainage Act of 1861. In addition there grew up during the 17th, 18th, and 19th centuries a great number of drainage authorities, in all 198, established under private and local Acts of Parliament. Another type of authority was established when common lands were being enclosed at the end of the 18th and the beginning of the 19th century to provide drainage for portions of such tracts. Still other authorities, about 114, were brought in under the Land Drainage Act of 1861. The Royal Commission of 1927 found in all 361 multifarious authorities uncoordinated and conflicting, leading to confusion.

The Act of 1930 was drafted, on the basis of the recommendations of the Royal Commission, to the effect that one authority should have charge of water control of a catchment area of each of the main rivers, with exclusive control over the main channel; and that it should derive its resources from the entire catchment area. The Act further authorizes the Minister of Agriculture and Fisheries to delimit catchment areas and to constitute Catchment Boards of such numbers of members as the Minister may determine, not in excess of 31. They are designated and appointed by the Minister in the following way:

(a) One member appointed by the Minister.

(b) Not less than three of the remaining members are appointed from their own numbers by councils[3] of the counties (rural counties) and of the county boroughs (cities) which lie in whole or in part within the catchment areas.

(c) The remaining members are appointed by the Minister after consultation and consideration of the nominations of the internal drainage district boards, whose districts lie within the catchment area. These members coming from local drainage districts are called the "low-land members" of the Board, and make the major contributions to the Board's expenses.

The powers of the Act confer on the Catchment Boards sole authority of the "main river" as designated on the official map, including the river banks and drainage works in connection with the main river. Authorities over water courses of all kinds, from watershed divides to the sea, are brought under unified jurisdiction. The authority extends to the sea or estuary shores abutting on the catchment, for purposes of providing an adequate outfall for the main river. It also extends to those works which provide for irrigation in the uplands; it provides for maintaining water levels during droughts and it may extend to control and ownership of accretions of land from

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[2] Report of Operations and Proceedings under the Land Drainage Act, 1930, Ministry of Agriculture. London, 1937.

[3] The County Councils are equivalent in authority to county commissioners or county courts of the United States.

silt deposits in estuaries resulting from works of the Board to provide for adequate water outfall.

After the catchment area is delimited and the Board is constituted, the Board is called upon to prepare and submit to the Minister of Agriculture and Fisheries a scheme for the river, which is to include:

(a) Provisions for the transfer to the Catchment Boards of all rights, powers, duties, obligations, liabilities, and of any property held by preexisting authorities within the catchment area.

(b) Proposals for alteration of boundaries of internal drainage districts, for amalgamation of all or parts of any internal drainage district, for abolition of powers and schemes of Commissioners of Sewers; for abolition of internal drainage districts and the boards thereof; for the constitution of new internal drainage districts within the catchment area; for amending regulations of existing boards, and in other ways for assuming full authority for all agencies and activities within a catchment area having to do with flood control and land drainage.

(c) Bylaws, which are to govern the administration of the catchment area, including internal drainage boards.

The Catchment Board is given powers of general supervision of drainage within the catchment area, to secure efficient working and maintenance of existing drainage works and the construction of new drainage systems, and to give such guidance as is necessary to the internal drainage boards with respect to their powers and duties.

The Catchment Board thus coordinates the plans and activities of internal drainage districts. Only where necessary will the Board take over the administration of an individual district. Rather it is the plan to retain the small drainage district's administration in force, but to readjust boundaries where advantageous, and to harmonize regulations for the conduct of the details of administration and collection of rates. Moreover, the Board has authority and power to construct or alter or maintain any works for drainage within its area in the interests of efficiency. Any questions arising out of conflicts are referred to the Minister for decisions; a report, with reasons for the action, is laid before Parliament for review.

In the event of conflicts involving the operation of other public or local acts, the Catchment Board may submit to the Minister for confirmation a scheme for revoking, varying, or amending such provision. The Minister may approve or amend any such scheme, except that when opposed it shall be provisional only and shall not have effect until confirmed by Parliament

In accordance with a stipulated procedure, the Catchment Board may exercise the powers of any internal drainage district in default, to prevent injury or possible injury of lands by flooding or inadequate drainage; and the Minister may transfer to a Catchment Board all powers, rights, and effects of an internal district.

A Catchment Board must take steps for the commutation of all obligations imposed on persons to do work in connection with the "main river," as determined by the Board to be just. In determining sums to be paid for the commutation of obligations, an interesting stipulation provides that no obligation will be waived which would reduce the discharge of tributaries into the main river as a result of changes in methods of cultivation of fields. Obviously, the intent here is to safeguard and foster land-use measures that will retard stream run-off.

On the basis of taxable assessed values, Catchment Boards may apportion the assessments among the councils[4] of the several counties and county boroughs that lie within a catchment area, and may further assess and require each internal drainage board to make toward the expenses of a Catchment Board such contributions as the Board may consider to be fair. In instances of disagreement as to the justice of the amounts assessed by the Board, the internal districts and councils may appeal to the Minister, who may call a local inquiry and issue an order as he thinks just. When the Minister makes such an order he lays and sets forth the reasons for his order. Compliance with any order made by the Minister for these purposes may be confirmed by mandamus.

Besides such precepted funds, Exchequer Grants may be made, as voted by Parliament, to finance improvement works for alleviation of unemployment and to advance improvement of water control more rapidly than is provided from local assessments. Such grants have been made on a conditional basis, to be matched by stipulated percentage contributions by Catchment Boards. In 1928 the Ministry was authorized to make grants of 50 percent of the net cost of projects of improvement or 75 percent of the wages cost of projects. This authority was extended to the Catchment Boards in 1930, was withdrawn in 1931, and again made available in 1935. Under this arrangement urgent comprehensive works have been undertaken. Such provisions are reminiscent of our P. W. A. grants.

The Catchment Board is required to prepare a set of byelaws for the administration of water control

[4] County Councils correspond to boards of county commissioners in the United States and county borough councils to municipal councils.

within its catchment area; these must be approved by the Minister before becoming effective. The Minister may confirm or modify the byelaws submitted, on the basis of protests or of governmental policy, in which case a full statement and reasons for such action are laid before Parliament.

The byelaws of one of the larger Catchment Boards, the Great Ouse of Eastern England, draining into "The Wash" may be cited. Apart from regulations governing the manipulation of weirs, locks, and similar works affecting water levels in the river, certain regulations have special interest in connection with soil conservation districts of the United States:

SEC. 4. "No person shall divert or alter the level of or direction of the flow of water in, into, or out of the 'river' without previous consent in writing of the drainage system of the catchment areas . . .

SEC. 6. "No person shall discharge or put or cause or knowingly suffer to be put or discharged or to flow into the river any gravel, stones, earth, mud, ashes, dirt, soil, rubbish, or any other matter of any kind whatsoever whether solid or liquid so as to tend directly or in combination with any acts of the same or any other person to obstruct the flow of water in, into, or out of the river."

Under this byelaw a farmer may be required to stop erosion on his fields when such erosion is delivering erosional debris into the river. Although the authority is not called into use for this purpose in England in the absence of serious soil erosion, yet the principle is established and would apply in the event of appreciable soil movement:

SEC. 9. "The occupier of land through which a water course flows or of land abutting any water course or the person having control of any water course shall upon being required by the Board by notice in writing within such reasonable time as may be therein specified cut all trees, willows, shrubs, weeds, grasses, reeds, rushes, or other vegetable growths growing in or into the water course and shall remove the same from the water course immediately after the cutting thereof,—provided that this byelaw shall not apply to the main river . . .

SEC. 11. "All persons using or causing or knowingly suffering to be used any bank of the river for the purpose of grazing or keeping any animal thereon shall take such steps as are necessary and reasonably practicable to prevent the bank of the river from being damaged by such use; provided that nothing in this byelaw shall be deemed to affect or prevent the use for the purpose of enabling stock to drink at any place to be made or constructed as may be approved by the Board . . .

SEC. 31. "Every person who acts in controvention of or fails to comply with any of the foregoing byelaws shall be liable on summary conviction in respect of each offense to a fine not exceeding twenty pounds [[$100]] and a further fine not exceeding five pounds for every day on which the offense is committed or continued."

Special attention is called to this continuing fine which according to reports brings about prompt compliance with actions of the summary or local courts.

Under the operations of the Land Drainage Act of 1930 the Minister of Agriculture and Fisheries has constituted 55 official catchment areas in England and Wales comprising the total land area, and has appointed members and approved their respective Catchment Boards. Byelaws of 27 Catchment Boards have been approved to date (1938). Grants in aid have been made to Boards on approved comprehensive improvement works involving up to March 1937 more than 4 millions of dollars.

The working of the law is bringing system out of confusion; the Act is regarded as a very important advance in regulation for the public interest of water control and land utilization affecting water control. The Minister of Agriculture and Fisheries, the Honorable W. S. Morrison, is pleased with the Act and with its operation, and expects that more inclusive authority affecting water resources, such as fisheries and navigation, may in time be assigned to Catchment Boards. Control of waters on a catchment-area basis has proved to be a solution to the problem of coordinating and simplifying authorities and regulations in water utilization and control.

In short, the Act of 1930 places upon the Ministry of Agriculture certain important authorities and functions such as the following: Creation of new and the amalgamation of existing catchment areas; the constitution of Catchment Boards and the appointment of some of its members; the confirmation of schemes submitted by Catchment Boards for the reorganization of their internal drainage districts; the preparation of maps of catchment areas and determination of the extent of the "main river"; the transfer of the functions of Internal Drainage Boards to Catchment Boards; the constitution of drainage districts outside catchment areas; the decision of appeals lodged by councils or internal drainage boards with regards to contributions from or to a Catchment Board; the confirmation of orders made by drainage boards for differential rating

or exemption from rating; sanctions for loans, and for the confirmation of byelaws.

The power of initiative of the Minister is limited under the Act. The Minister cannot require a Catchment Board to submit any particular scheme or project; he can only confirm, with or without modifications, or withhold confirmation from a scheme which has already been submitted. But under the Act he may require that schemes be presented and approved as a condition of grants by Parliament for improvement works by Catchment Boards.

Conservationists in the United States will follow the working of this development in England with interest.

OUR DRAINAGE PROBLEMS

(Continued from p. 182)

construction of smaller projects. The local drainage enterprises have furnished all material required for the work projects except small amounts used for demonstration purposes and the draglines used for most of the work. Altogether they contributed about 50 percent of the excavation costs.

Table 4 gives a summary of the accomplishments of the 36 C. C. C. drainage camps originally established in Ohio, Indiana, Kentucky, Illinois, Iowa, and Missouri from July 1, 1935, to December 31, 1938. The record of camps in other States is about the same.

TABLE 4.—*Accomplishments of the 36 C. C. C. drainage camps in Ohio, Indiana, Kentucky, Illinois, Iowa, and Missouri, July 1, 1935 to Dec. 31, 1938*

Type of work	Total amount	Amount per camp month
Net area benefited..........acres..	6, 275, 000	4, 610
Ditches cleared..........miles..	5, 907	4. 3
Clearing on ditches..........square yards..	182, 698, 000	134, 238
Levees cleared..........miles..	440	0. 3
Clearing on levees..........square yards..	19, 536, 000	14, 354
Ditches excavated..........miles..	3, 328	2. 4
Ditches excavated..........cubic yards..	37, 183, 000	27, 320
Levees repaired and rebuilt..........miles..	146	0. 1
Embankment constructed on levees......cubic yards..	2, 172, 000	1, 596
Spoil banks leveled..........miles..	1, 511	1. 1
Spoil bank leveling..........cubic yards..	8, 583, 000	6, 306
Tile lines repaired and rebuilt..........miles..	237	0. 2
Structures repaired and rebuilt..........	3, 542	2. 6
Value of cooperation furnished..........	$3, 140, 189	$2, 307
Cooperation per acre benefited..........	$0. 50	....
Estimated commercial value of work..........	$12, 719, 000	$9, 345
Commercial value per acre benefited..........	$2. 03	....
Enrollee time utilized..........man days..	3, 303, 774	2, 427
C. C. C. camp time expended..........camp months..	1, 361	....

The State extension services have cooperated in the location of camps, in the determination of work policies in the various States, and in furnishing advice relative to drainage camp work operations. Many county agents have taken an active interest in the selection of projects and the execution of the work program. This cooperation is considered of the greatest value in administration of the work.

The need for a supplementary erosion-control program in connection with the drainage camp work has been apparent. Much erosion debris, particularly from adjacent hilly lands, fills the ditches. The recent departmental reorganization and transfer of the drainage activities to the Soil Conservation Service will enable a more comprehensive land-use and erosion-control program in future camp activities.

RESEARCH PROBLEMS

(Continued from p. 185)

pose of survey a few of them are pointed out as of interest to the engineer. The whole field of the hydraulics of erosion is practically untouched. Unexplored problems involve such as these: The entrainment or picking up of erosional debris, its movement as bedload or suspension, and sorting and deposition; the energetics of flow causing erosion and its relation to the design and effect of structures; the use of vegetative materials for run-off channel linings; studies of land slides and slips; "mudflows"; the aerodynamics of wind erosion; the erosion problems connected with irrigation; the relationship of snow covers to erosion processes; the control of mountain torrents, etc. There is practically no end to the practical problems which if thought through to their fundamentals and investigated, present an almost unlimited field of service for the agricultural engineer, the agronomist, and the soil technologist.

RUN-OFF STUDIES

(Continued from p. 190)

occurred on W–II. Although 0.88 inch of rain fell within the preceding 24 hours, the July 16, 1939, rain produced a peak of only 0.53 c. f. s. per acre, which is only one-fifth of the March 30, 1938, rate. The maximum rate of run-off resulting from the August 17, 1939, rain was 0.82 c. f. s. per acre, which is about one-third of the March 30, 1938, rate, yet the total amount (4.75 inches) of this rain was more than twice and the intensity for the "time of concentration" was about 70 percent greater than those of the March 30, 1938, rain.

The writers hope that the few examples discussed in this paper will illustrate the type of information being obtained from the run-off studies on demonstration projects and the absolute necessity of complete and careful analyses before the results can be used as a basis for design.

ENGINEERING AND PLANNING

(Continued from p. 169)

and impervious clay was found within 2 feet of the surface except in the drainageway. The best location for the sodded spillway is at the north end of the fill. The pond will be fenced and water piped through the fill to a watering trough below. No treatment of the pasture will be necessary. The woods, Field 7, will be fenced from the pasture and proper management practices will be followed.

A study of the completed plan for the three farms shows that there are engineering problems on all fields except the existing and proposed forested area. Most of the terraces will outlet individually into pastures, and only one short sodded channel will need to be built. The development of a meadow along the drainageway through the Blake and Stewart farms will prevent soil from being washed down on to the Stewart farm and will provide a needed source of hay. The proper location of field roads is a factor that frequently is overlooked. In this case it has been possible to provide access to all parts of the farms without crossing terraces, with the exception of a small area in Field 6 of the Blake farm.

Although it will be necessary to postpone the reconstruction of some of the terraces pending establishment of pasture and meadow cover and the construction of one sodded channel, this will not actually cause any delay in the application of the conservation program on these farms, since there is insufficient power available to complete the work the first year.

For the Blake farm, the first-year program of work may include the following: The development of the meadow, Field 5; the fencing of the woods and construction of the spring collecting basin and stock-watering tank; leveling of old terraces in Field 6 and the construction of new terraces; the building up to adequate size of old terraces in Field 4; and the sodding of the short portion of the highway ditch in front of the farmstead as soon as it has been resectioned.

The first-year work program for the Morris farm may include the leveling of old terraces and construction of new terraces in Field 1, the sodding of the land being retired to pasture, Field 2, and the construction of the farm pond, fencing the woods, and the sodding of the highway ditch along the north boundary line.

The first year's work on the Stewart farm may include these operations: Contour furrowing and sodding of the land being retired to pasture, Field 1; establishment of the meadow, Field 3; leveling old terraces and building the new terraces west of the field road in Field 4 provided the terraces on the Blake farm have been constructed; the excavation and sodding of the outlet channel and flume at the south side of this field; tree and shrub planting in Field 5; construction of the stock pond in the pasture, Field 6; and the fencing of the woods.

This has been a presentation, in as brief a form as possible, of the procedures and major considerations involved in the planning of farms and the development of a work schedule. Thus we see that agricultural engineering is an integral part of all farm planning, and engineering planning is inseparably associated with other planning aspects.

WATER-FACILITIES PROGRAM

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irrigated from the Sublett reservoir. Fundamentally, the land-use adjustments are improvements in the present practices and farming methods. These modifications involved the incorporation of grass and alfalfa stands to assist in weed control and to increase the quality and palatability of the feed. Pastures will be improved by the inclusion of more palatable, nutritious and early growing species, and grazing will be rotated at proper intervals to maintain weed-free stands of improved carrying capacity. Alfalfa rotations will be shorter to permit the maintenance of high-yielding stands and to sustain fertility and physical structure of the soil.

Grass was found to be desirable in at least 50 percent of the acreage seeded to alfalfa. Dry lands cropped with a grain-fallow system will be placed in a long-time grass rotation, the grass being utilized for seed, hay, or pasture. Contour cultivation, stubble utilization, trashy fallow, and restricted grazing of crop aftermath will be practiced. Grazing lands and pastures will be grazed in accordance with estimated carrying capacities. Necessity requires that the Sublett ranchers comply strictly with the grazing requirements on the Forest Service and Public Domain grazing allotments to ensure permanency of the grazing resources and to lessen the danger of erosion and damage from silting of Sublett reservoir.

BOOK REVIEWS AND ABSTRACTS

by Phoebe O'Neall Faris

NOTE.—The Soil Conservation Service presents as guest reviewer its distinguished collaborator, Dr. Paul B. Sears. Formerly with the University of Oklahoma, Dr. Sears now heads the botany department of Oberlin College. An able educator, ecologist and writer, Dr. Sears is widely known for his authorship of *Deserts on the March*, *This Is Our World*, and *Life and Environment*.—THE EDITOR.

SOIL CONSERVATION. By H. H. Bennett. New York. 1939.

The campaign to protect and restore our soil is in some respects the most dramatic event in American peacetime history since the winning of the continent. It differs from all great national episodes which have preceded it in the degree and steadfastness with which it utilizes scientific knowledge.

Most great movements of history have their fiery apostles, their practical leaders, and their chroniclers. Seldom are these three functions combined in one individual as Hugh Bennett (a southerner by birth and training) combines them in the campaign to restore the diseased landscape of this great Nation. If the present volume served no other purpose than to bear witness to this notable fact, it would be significant.

There is no need, however, for the book to rest on its symbolic importance. It is, in its own right, one of the most impressive and potentially useful books to issue from an American press in recent years. It consists of 43 chapters occupying almost a thousand pages, carefully indexed, and illustrated by 358 excellent figures, most of them from the files of the Soil Conservation Service which Dr. Bennett heads. The simplicity and clarity of the language, even when dealing with technical matters, is remarkable. The book throughout is marked by straightforward, lucid, frequently arresting exposition.

The theme of soil conservation divides itself naturally into three major divisions: The process of soil destruction; the consequences; and the problem of control. Dr. Bennett's discussion follows this order. In the preface, Dr. Bennett acknowledges his indebtedness to a considerable number of the brilliant scientific workers whom he has gathered about himself in the Soil Conservation Service. Thanks partly to the colabors of these men, many of the chapters represent the finest, best balanced, and most noteworthy discussions of their particular topics that are available anywhere in English in such brief compass. This is true, for example, of the chapters on "Erosion and Civilization," "Climate and Soil Erosion," "Wildlife and Soil Conservation," "Early Efforts Toward Erosion Control," and "Erosion Problems in Foreign Countries." There is also much that is newly assembled in the chapters on the technique of control.

It is hazardous to attempt to formulate a writer's philosophy even after reading such a comprehensive volume as the present. We can be sure, however, that Dr. Bennett regards soil erosion as primarily a human problem; that he believes that the means have been devised for its solution; that permanent agriculture is possible even where the land is highly vulnerable to erosion when people are willing to pay the price of protection. He is unequivocal in his belief that where this price is not paid, civilization disintegrates.

It is also clear that while Dr. Bennett believes the restoration of the soil to be a national problem, calling for a national program, he does not at all believe this has to mean that the Federal Government shall regiment and control. He is explicit in his endorsement of democratic processes of approach to this national program.

Dr. Bennett recognizes education as a prime instrument in securing democratic action. It appears to be his belief that there is no instrument of democratic education superior to the use of demonstration areas. His insistence on this point is worthy of record by those interested in the applications of science, in teaching, and in political life.

Equally important to those interested in the application and teaching of science are other features about the book. It is documented throughout from original sources with all of the care of a monograph. Perhaps, unconsciously too, it represents a new emphasis on the use of science for the common good. Heretofore the dominant note in applying science has been its utility in devising new ways and means to circumvent old consequences. This book is a demonstration of the utility of science as a means of getting our bearings and coming to terms intelligently with nature instead of trying to outwit her.

Dr. Bennett rightly and frequently stresses the need for continuing research. With this point of view anyone who understands science must agree. At the same time he makes it quite clear that we already know enough to make matters far better than they now are. Perhaps without realizing it he is here caught in the dilemma which faces any public servant who would give to the public the benefits of his own scientific knowledge: an unbelievable amount of energy must be spent in obtaining overwhelming proof of many matters already quite clear to the scientist himself. Like the flattery which Disraeli administered to his sovereign with a trowel, scientific evidence must be poured forth upon the voting public in overflowing and often expensive measure in order to get action. This is true even where self-preservation is at stake—as public health authorities well know.

The editorial and manufacturing work on the book is of excellent quality. The actual errors which came to the attention of this reader are very few indeed. On page 897 the famous Maj. John W. Powell is reduced to the rank of lieutenant. If he deserves any posthumous change of status, it is promotion.

Even such a thorough going volume as the one under review must submit to limitations of space and emphasis. So far as the reviewer is concerned, this is apparent in the discussion of insects and of weeds. In both instances the viewpoint of modern ecology, especially as it refers to living communities and the manner of their development, might have been employed to advantage. There is reason to believe, for example, that many insects (and rodents) are more important in accelerating erosion once it is under way because of disturbed natural conditions than they are in producing the initial disturbance. And the relation of weeds to erosion control becomes highly significant when they are viewed as pioneers in plant succession, making way for more permanent, better integrated communities. It is these balanced and integrated communities—as distinct from mere "plant cover"—which are the active agents of soil genesis, to say nothing of stabilization. Their importance in the field of operations, future agronomic, range, and forest practices is vital. For that reason, perhaps, the reviewer regrets to see any lost opportunity to emphasize the ideas of community and community succession.

But this omission is more than offset by Dr. Bennett's frequent and effective emphasis on the indispensable role of vegetation in soil conservation, and the corollary that engineering techniques must take cognizance of this great principle.

The reviewer feels safe in predicting a world-wide reception to this volume.

—PAUL B. SEARS.

U. S. GOVERNMENT PRINTING OFFICE: 1940

THE COMMON BOND OF LAND USE

By H. H. BENNETT [1]

Land utilization has long been a familiar term to the Soil Conservation Service. Wise use and protection of the land has been the basis of all our conservation efforts. This fact alone indicates the common thread that runs through the soil-conservation program, bringing together the original erosion control work and other lines of endeavor, including the program that has borne the name of "Land Utilization."

For the past year I think that everyone in the Service, from those who started with the old Soil Erosion Service to those who more recently joined forces in the enlarged Service program, has been going through an educational period. The reorganization of the Department, unifying several lines of work under the banner of soil conservation, has forced us to broaden our concepts and understanding of this work. In terms of land utilization, for example, we have expanded our thinking and our action from promoting sound land use on individual farms to carrying out improved land-use programs over large areas that include groups of farms and much land that is not, or should not be, used for cultivation.

This is one of several contributions that the land-utilization program has made to our campaign to develop an agriculture geared to the maintenance and improvement of land resources. The work in submarginal farm areas has also brought to our

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attention many new and significant facts about land use—for example, the tremendous amounts of money that have been wasted in the drainage and improvement of infertile soils, or the fact that in many communities the cost of educating the children of families on poor lands is several times greater than the amount those families pay in taxes.

Of course, the purchase of land is merely a means, not an objective, in the program—just as on a single farm, proper utilization of a purchase area means the assignment of land to its best use by means of a detailed plan of management for the entire area.

In the Great Plains, local stockmen, organized in cooperative grazing associations, are using the lands purchased by the Government, in connection with their own private holdings. The range improvements, such as water supplies and fences, have been put in as an aid for increasing the carrying capacity and usefulness of both public and private grasslands. In other parts of the United States, purchased lands are developed principally for forestry or wildlife. In this work men are being used who need additional sources of income to supplement what their own farms will produce.

The close connection between soil conservation and land utilization was one of the reasons that led to the incorporation of these two activities in one coordinated program. Experience has clearly shown that no one solution will liquidate our national or regional land problems—problems in which the physical condition of the land is intimately influenced by human ownership and use.

Specifically, there are few, if any, areas in which conservation of the land can be achieved only by working on individual farms. Sooner or later, in many farming areas of the United States, we reach the point in erosion-control work beyond which it may not be possible to produce the necessary

results. It may be that some farms, for example, are too small for the type of agriculture that will conserve the soil and at the same time support a family. On the other hand, there may be farms on which so much of the land is classed as unsuited to cultivation that it is rightly termed "submarginal." Here is where the land-utilization approach steps into the picture, providing the means of a more rewarding readjustment of land use as dictated by physical and economic considerations.

On the other hand, experience of the land-utilization projects has proved a similar point. There are few areas of the United States where land use is so completely out of line with the productive character and permanence of the land itself that Federal purchase is the only means of untangling the problem. Recent projects have tended to emphasize the acquisition of land in limited amounts, leaving as much of the area as possible in private hands. The over-all plan then brings together both public and private lands in a pattern of use and management that applies conservation to the entire area.

In the Department's broad land-use program, the Soil Conservation Service is now charged with a tremendous and challenging responsibility. It has an obligation to maintain and protect the soil resources of all the farm lands from which American families are trying to win a living—from the gently sloping lands where erosion is hardly noticeable to the gullied and worn-out tracts of the more rolling, older farming sections, or the lonely clearings in the peat bogs of the Lake States, where misuse of the land has all but rotted away the opportunities for profitable use. One purpose of the reorganization was to consolidate in one agency most of the available weapons for a broad campaign, using all practical measures coordinated as a single implement, in order to establish good land use as the basis for a stable and permanent agriculture.

THE COMMON BOND OF LAND USE

CONTINUED

Obviously, this campaign will not attain its objective within a brief period of time. The progress already made, however, indicates the specific nature of its methods and objectives.

The program that is now being formulated in Greene County, Ga., provides a good illustration of unified effort at work. Here, within a soil-conservation district, we find all the arms of the Service, as well as other branches of the Department, working together, coordinating their efforts. Co-operation with the soil-conservation district for erosion-control work is safeguarding the soils of the land that have not yet been damaged too seriously for cultivation. Rougher lands, on which soil destruction has proceeded to the point where private owners cannot hope to manage the land profitably, are being purchased in selected tracts and developed for forestry, wildlife, and grazing. The development and management of these tracts are being worked out in conjunction with the plans for the improved use of adjoining private lands. These joint activities on the land itself, plus the important attention to social and economic factors provided by the Farm Security Administration and State agencies, frame an understandable picture of how the Department's complete farm program is fitting together.

Essentially the whole program of the Service in Greene County is one of establishing security for the land and the man on the land, reducing the hazards of floods and siltation, and rehabilitating wildlife resources on the farm through improved land use and land management. As a result of the operation of the soil-conservation districts, we are in all our work having to think more in terms of large areas and adjustments among communities as well as in terms of the individual farm. As that viewpoint develops, the fundamental unity of the land-utilization program with other activities of the Service stands out ever more clearly.